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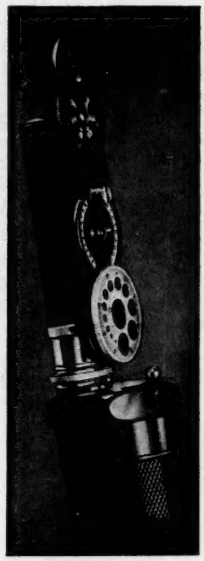

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COMMUNICATIONS

A RECORDING TONOMETER*

BY

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THE measurement of the resistance to outflow of the aqueous humour by the procedure of tonography has recently aroused interest in the continuous recording of the intra-ocular pressure (IOP). There are, in addition, numerous other physiological and clinical investigations which could be performed if it were possible to obtain a continuous and accurate record of the IOP in human subjects. Such recordings have been obtained using the Müller electronic tonometer connected to a suitable amplifier and recording galvanometer. This arrangement, however, suffers from several disadvantages. First, the tonometer must be held continuously on the patient's eye by an operator, and this limits the time during which the record can be continuously taken. An improvement may be effected by using a mechanical holder, such as that designed by Merté (1957), but some supervision would still be required. Secondly, the fact that it is impossible for the patient to move his head makes many experimental procedures impossible. Thirdly, the Müller instrument, being basically a Schiötz tonometer, suffers from the defects of this instrument, principally that its application to the eye raises its IOP to about double its original value (Friedenwald, 1954), the extent of the rise varying from eye to eye in a not readily determinable manner.

The instrument described in this paper is essentially a research tool and is too complicated for widespread use as a routine clinical instrument. It was designed to be mounted on the patient's forehead and to maintain its position on the eye without attention and regardless of the position of the patient's head. In addition, it seems to be intrinsically more accurate than the Schiötz tonometer. The theoretical principle on which it operates and its practical construction are first explained, and further sections describe its method of use and its performance. Only the results of investigations into normal eyes are reported in this paper; it is intended to publish studies on glaucomatous patients later. Finally, an account of the calibration of the tonometer on human cadavers is given, from which the value of the normal IOP is derived.

* Received for publication July 16, 1957.

Operating Principles

This instrument measures the force necessary for a plunger to make a definite indentation into the eye. This has advantages over the customary mode of operation which measures the depth of indentation under a definite force:

(1) Since the volume of the indentation does not change as the IOP varies, the instrument responds more rapidly and accurately to these variations. Similarly, the analysis of the changes of pressure with time in tonography will be more simple because there will be one less variable quantity.
(2) Since the shape of the indentation does not change as the IOP varies, the relationship between indentation force and IOP should be linear.

The basic design of the instrument is shown schematically in Fig. 1. One end of the plunger P indents the cornea, and the other bears against the pressure-sensitive element R. The plunger slides in the body B, the lower part of which is formed into a conical foot F, which, near its rim, rests on the cornea.

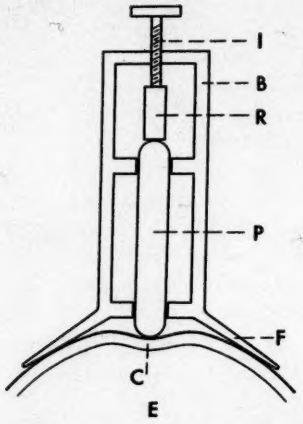


Fig. 1.—Schematic representation of recording principle.

The instrument is pressed on the cornea with a predetermined force, normally 10 g., and the plunger indents the eye to a predetermined depth, normally 0·5 mm. This 10-g. force is then divided between that required to give the plunger its indentation (0 to 8 g. according to the IOP) and the remainder (10 to 2 g.) which is supported by the foot.

There are two advantages in the rim of the foot being in contact with the cornea rather than the centre as in the Schiötz tonometer. First, it will not slip off the eyeball and will maintain its position without continuous attention. Secondly, the volume of fluid displaced by its impression is smaller. To take an example, a Schiötz tonometer with a 5·5-g. plunger weight resting on an

eye of 17 mm. Hg IOP will make contact with the cornea over the entire area of the foot-plate, 72 mm.^{2} (Friedenwald, 1954), and will displace approximately 30 mm.^{3} of fluid. The total weight of the same tonometer (16·5 g.) pressing on a conical foot touching the cornea round a circle of 8 mm. diameter will make about the same area of contact but will displace only 10 mm.^{3} of fluid. If the weight is reduced to 10 g., only 2·5 mm.^{3} will be displaced.

Against these advantages must be set the disadvantage that, if the plunger is in a fixed position relative to the foot, its indentation and therefore the force acting on it will be affected by the curvature of the cornea. To eliminate this source of error, in each eye the indentation is measured from the point of contact of the plunger with the cornea. This can be effected by altering the position of R relative to B. When the instrument is first placed on the eye, R is raised so that it is not touching the plunger; it is then lowered until contact is recorded and then further to the required depth of indentation.

To permit small movements of the eyeball, the foot and plunger are mounted on a universal joint U, attached to an arm (Fig. 2). The arm is

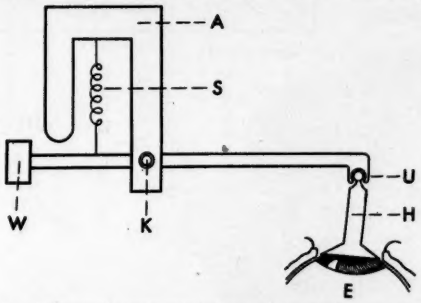
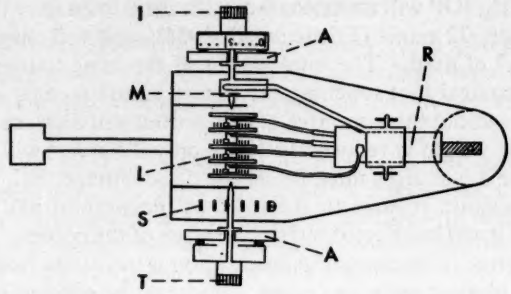


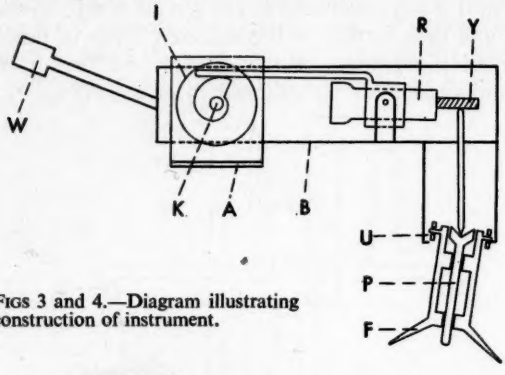
FIG. 2.—Schematic representation of tonometer mounting.

counterbalanced and pivoted in a frame A, and a spring S between the arm and the frame keeps the foot pressed on the eye. The shorter the distance between U and the cornea, the greater will be the stability with which the instrument rests on the eyeball. On the other hand, if it is too close, it is difficult to adjust the position of the foot correctly upon the cornea and small rotations of the globe will not be adequately compensated for. In preliminary tests a distance of 15 mm. was found to be a suitable compromise.

CONSTRUCTION

The construction of the instrument is shown schematically in Figs 3 and 4, and by photographs in Figs 5, 6, and 7 (overleaf). The foot F is made of transparent plastic (Perspex) and its internal conical surface is 10 mm. in diameter at its base and makes a 60° angle to the axis. A small hole is drilled through the cone near its apex to prevent it from attaching itself to the eye by suction. The plunger P is made of stainless steel tubing of 1·47 mm. external diameter. A convex spherical tip to the plunger would tend to press into the cornea at its centre and a concave or flat one at its edge. A profile of a half ellipse of axial ratio of 2 : 1 was therefore made,





FIGS 3 and 4.—Diagram illustrating construction of instrument.

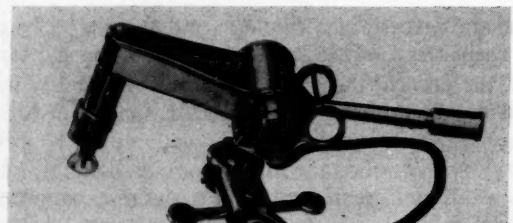


FIG. 5.—Photograph of tonometer.

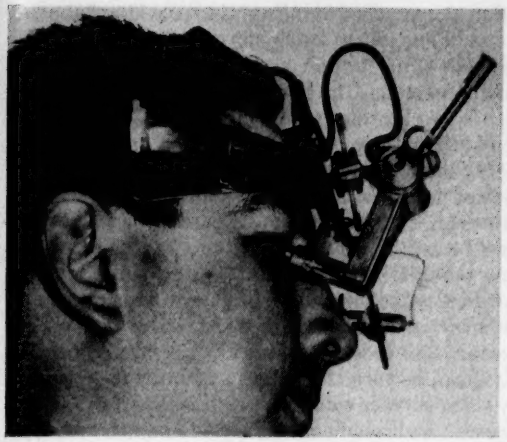


FIG. 6.—Instrument in use.

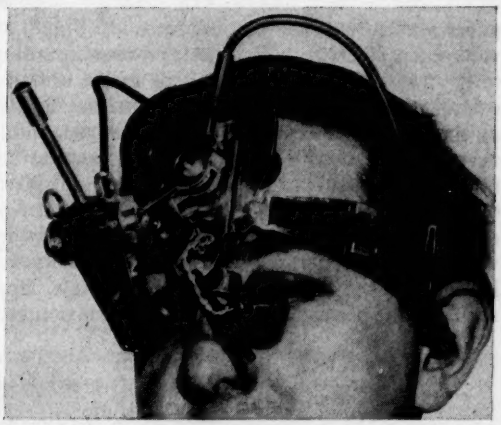


FIG. 7.—Instrument in use.

in the hope of reducing its pressure on the cornea to a low and uniform value over the area of contact. The plunger slides freely in two bearings in the foot and the space between them is filled with a light oil which lubricates the bearings and prevents tear fluid fouling them.

The foot is mounted in gimbals U, 15 mm. from the base of the cone. The plunger ends in a conical socket and its length is fixed at 13·8 mm., so that when a cornea of average radius is indented by 0·5 mm. the apex of the socket is in line with the gimbal axes. The foot and plunger may be detached together for cleaning. The socket is engaged by the pointed tip of a rod which bears against the pressure-sensitive element at its other end. A loose bearing at this end guides the rod.

To record the force on the plunger a mechano-electric transducer valve R (RCA 5734) is used as the pressure-sensitive element. This is a triode, the plate of which is connected through a flexible seal to an external stylus, so that a force applied to the stylus will slightly deflect it and change the current through the valve

proportionally. A plastic extension *Y* is attached to the stylus to provide a flat bearing surface for the rod.

The valve-mounting and the gimbals of the foot are attached to the body *B* of the instrument which is made of thin dural sheet. The body is pivoted in a frame A on two pointed steel rods which engage two bearings mounted internally in the body. These rods can be rotated by two knobs mounted on the frame and normally fixed to it by friction. The rotation of one knob *T* winds a flat spiral spring *S* attached to the rod at one end and to the body at the other, so that the foot is pressed on to the eye. The knob is connected through a slow-motion drive to a concentrically mounted dial which is calibrated in terms of the force on the foot.

The other knob I controls the plunger indentation. The transducer valve is mounted in a pivoted bracket which is rocked by means of an arm bearing against a cam M turned by the rod. In this way the stylus is moved towards the eye and presses the plunger into the cornea. The indentation scale is engraved on a ring which rotates round the knob and can be turned to bring its zero into alignment with an index mark on the body when contact with the cornea is first registered.

The electrical connexions to the valve are brought out through light spiral springs *L* wound round the pivotal axis of the body. The output is passed through an amplifier and led to a pen-and-ink recorder (Fig. 8). The amplifier has one stage of voltage amplification and a triode power output stage. Negative feedback is taken to the transducer from the cathode of the output stage, in order to improve the overall linearity and stability of the system. By altering the degree of feedback the sensitivity of the instrument may be changed, and three ranges are provided which may be selected with a switch. Full-scale movement of the pen on two of the ranges corresponds to an IOP of 0–80 and 0–30 mm. Hg when the indentation is 0·5 mm. The total movement on the third scale represents 8 mm. Hg, but by means of a control knob on the amplifier its zero may be adjusted to correspond to any value of the IOP so that its variations can be observed with full amplification at any level. The pen recorder writes on a 4″-wide paper strip and its response time is such that the pen can move from zero to maximum deflection in 0·1 sec. The paper

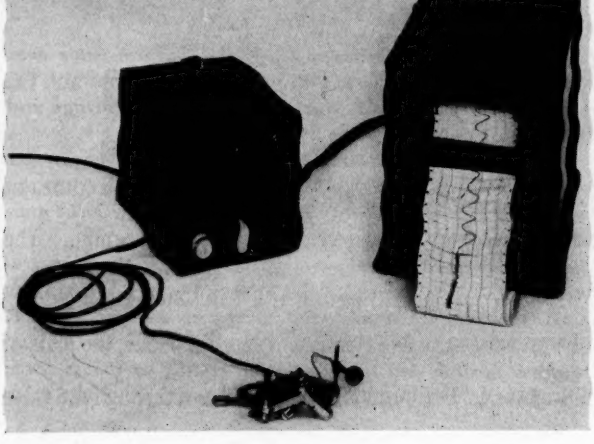


FIG. 8.—Instrument connected to amplifier and penwriter. The foot is protected by a cap.

normally moves at a speed of 1"/min., but it can be increased to 1"/sec. by pressing a push-button switch on the panel of the amplifier. Incorporated in the amplifier, also, is a switch which damps out rapid variations in the electrical response of the tonometer such as those caused by the pulse, so that the average level of the IOP may be recorded directly.

In use the instrument is mounted on a headband on the subject's forehead. The band is supported on the bridge of the nose and two points on the forehead and is held in position by an elastic strap round the back of the head. Two arms resting on the temples prevent it from rocking. A socket on the front of the headband is engaged by a plate which is connected by a double ball joint to the frame of the tonometer. The socket and plate allow the instrument to be freed from the headband while it is being adjusted or while the calibration of the instrument is being checked. The link of the double joint can be clamped by a small movement of a locking arm. When it is free the axis of the tonometer foot can be readily adjusted in all directions; when it is clamped it is locked rigidly to the headband. A fixation target is attached to an arm which is also mounted on the plate. It can be focused to suit the vision of the subject, and it is illuminated by a light, the intensity of which is adjustable by a control on the panel of the amplifier. The target is surrounded by an opaque screen to prevent other objects in the field of view distracting the subject. The weight of the complete instrument, including the headband, is 130 g. (4½ oz.).

A balance for checking the calibration of the tonometer has also been constructed. It has two arms, one of which balances the force on the foot and the other applies known forces to the plunger. The tonometer is attached to the balance by means of a socket similar to that on the headband. The foot fits over a plastic sphere of 8 mm. radius on the end of the first arm, and the tension of the spring is adjusted to support weights placed on the other end. A hole is drilled in the sphere through which passes a plastic rod attached to the end of the second arm. This rod pushes against the plunger with a known force when weights are placed on the pan at the other end of the arm.

Method of Use

The subject lies down and the headband is fitted tightly but comfortably. The eye to be examined is well anaesthetized and a drop of parolein is instilled to lubricate the surface and reduce trauma. Fixation over considerable periods is made more comfortable if the other eye is also anaesthetized lightly. The instrument is fitted on the headband and the fixation target is focused for the far point and adjusted so that the eyes look slightly down from the primary position. The plunger of the tonometer is retracted and the spring set at 10 g. force on the foot. The instrument is gripped by the frame, the link on the ball joint is unclamped, and the foot manoeuvred under the lids. It is then adjusted until the foot appears to be centrally situated on the cornea and perpendicular to the tonometer body, and the link is then clamped. With experience it can be positioned in about a quarter of a minute without difficulty.

With the amplifier set to its most sensitive range, the plunger indentation control is turned until a deflection of the pen is noted, showing that the plunger has touched the cornea. The indentation scale is rotated until its

zero coincides with the index mark on the body and the contact point is checked; agreement to the thickness of a line on the scale, better than 0·01 mm. is generally reached. The amplifier is then switched to a less sensitive range and the indentation control knob turned to the required position. The instrument then records without further attention and the subject can make what movements he chooses provided his gaze remains fixed on the target.

If it is desired to examine the pulse wave in detail the amplifier is switched to its most sensitive range and the pen is brought to the middle of the paper with the zero control. The paper is then driven at 1″/sec. by pressing the control button.

Performance

The instrument can be worn comfortably by most people; only two out of some hundred subjects squeezed their eyelids so much as to make its application impracticable. The foot has never been displaced by blinks and remains steadily in position when the subject rises to his feet or undertakes quite violent exercise such as "knee-bends". The instrument has remained on the eye for periods of up to 20 min. with less trauma to the eye than caused by tonography with the Schiötz tonometer, and no subsequent discomfort. The experiments are limited in practice by the difficulty in maintaining fixation over longer periods.

The force recorded by the instrument after reaching its initial level undergoes a slow decline, but it levels off at a more or less steady value after 2 to 4 min. (Fig. 9).

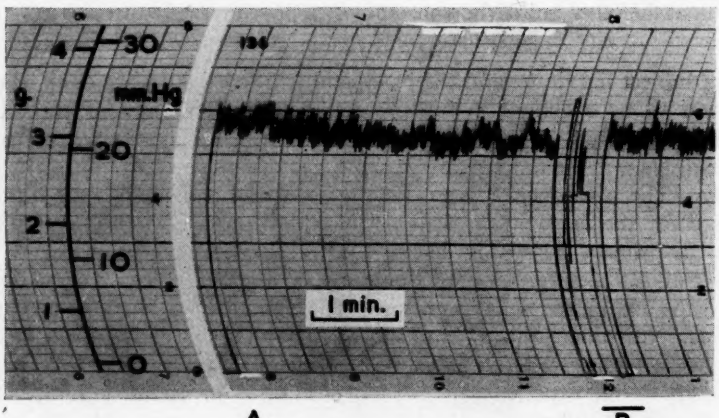


FIG. 9.—Typical tonometer recording.
A, initial plunger indentation. B, check of plunger contact and re-indentation. The scales show the force on the plunger (g.) and the corresponding IOP (mm. Hg).

In most cases a part of this drop results from the indentation of the material of the cornea itself so that the impression of the eye is effectively less than 0·5 mm. This is made evident by checking the contact point after the steady value is reached, when it is found to have shifted by up to 0·05 mm. in eyes with a high tension but generally between 0 and 0·02 mm. in normal eyes. To avoid error in estimating the value of the IOP, the contact point was checked at the end of a recording as a routine, and the plunger reinserted by 0·5 mm. from the new position. A new level was quickly reached, and this was taken as corresponding to the correct value of the IOP.

The true tonographic drop is due to the return of the pressure to its normal value, after it has been raised by the first application of the instrument. It is measured as the difference between the reading when the cornea is initially indented by the plunger and the correct value of the IOP estimated in the way described above. The total extent of this drop—about 20 per cent. of the IOP on the average—is much smaller than that shown with the Schiötz tonometer; this corresponds to the greater rise in IOP caused by that instrument.

The IOP record shows variations about the mean level due to the pulse and other causes. The pulse wave does not show any fine detail but is generally rather flattened on the high pressure peaks (Fig. 10). The pulse amplitude appears to differ remarkably between normal subjects, a range of 5:1 being recorded. The amplitude may fluctuate in an irregular manner on an individual record, occasionally by as much as 100 per cent. No correlation between pulse amplitude and age or tonographic fall was shown.

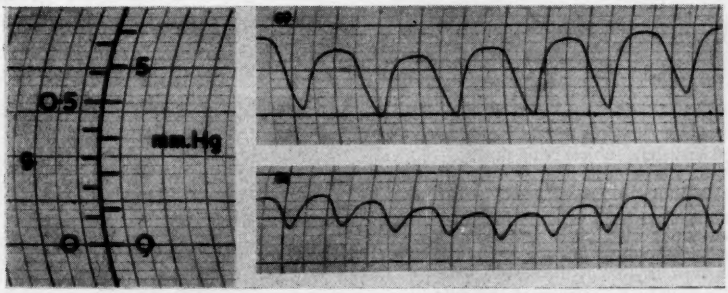


FIG. 10.—Intra-ocular pulse in two subjects. The scales show change in force on plunger and change in IOP.

The possibility that the observed pulse is a result of rotary or exophthalmic movement can readily be eliminated. The former can be made voluntarily during a recording and the latter may be simulated by grasping the frame of the instrument and moving it to and fro against the subject's forehead. In order to create an artificial pulse of an intermediate size, rotations of about 1° and exophthalmic movements of about 1 mm. were necessary. Movements far smaller than this would be detected subjectively or objectively if they occurred in a normal recording.

Some results showing the potentiality of the instrument as a tool in physiological research may be of interest. Fig. 11 shows the effect of forced expiration against a pressure of 5 mm. Hg in a normal subject. It is seen that the IOP rises to 150 per cent. of its normal value and that the pulse variation is suppressed. The effect of rising to the feet is shown in Fig. 12. A correction of 250 mg. has to be made for the weight of the plunger rod and stylus which is supported by the cornea when the subject is recumbent but not when he is erect. On sitting or standing there is generally a rapid rise in IOP followed by a drop below the normal value. The pressure reaches an average level which on correction is very little different from that found when recumbent: from the few cases that have been investigated there is a suggestion that there is a drop of about 1 mm. Hg.

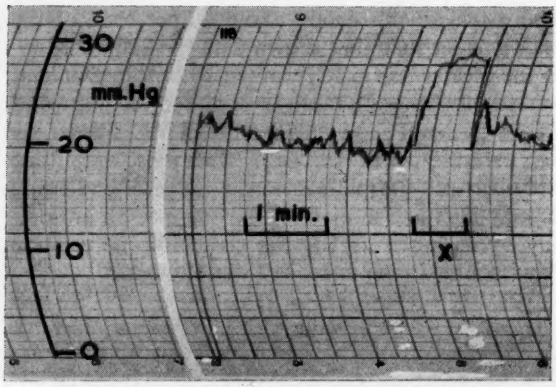


FIG. 11.—Effect of blowing (X) against a column of mercury.

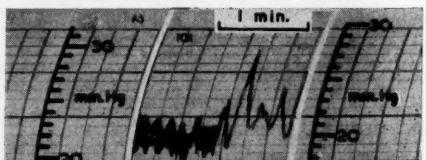


FIG. 12.—Effect of rising to feet.
A, and scale left, subject lying down;
B, subject sitting up;
C, and scale right, subject rising to feet and standing.
In this subject the pulse amplitude is reduced in standing, and the amplitude of the slow rhythm is increased; some subjects show little change in the appearance of the record.

CALIBRATION

The instrument was calibrated on human cadaver eyes *in situ*. This procedure should reduce the error caused by the exaggerated distortion of the eyeball by the tonometer if it is not supported under natural conditions (Friedenwald, 1954). The eyes were cannulated and connected to a saline manometer so that a determined pressure could be developed within them. A stopcock was introduced between eye and manometer so that measurements could be made either when they were in free connexion—open stopcock measurements—or when the eye was isolated from the manometer, the

required pressure having been established within it—closed stopcock measurements. The difference between these two measurements is the rise in pressure caused by the application of the tonometer to the eye, and is determined by the rigidity of its outer tunic and the volume of the tonometer impression (Friedenwald, 1954).

It was found in preliminary trials that, when the eye was cannulated in the anterior chamber, there was a considerable difference between open and closed stopcock readings, but that this difference was almost negligible when the eye was cannulated in the vitreous body. It was observed in the former case that the anterior chamber became very deep in the course of the experiments and that it appeared unnaturally shallow in the latter. It is probable that part of the pressure in the cannulated chamber was being supported by the lens and zonule and not communicated to the other chamber. The distensibility of the dilated anterior chamber would be less than that of the eye as a whole and would thus lead to a larger rise in pressure when the stopcock was closed and the tonometer applied. It was considered that, to make the conditions as near normal as possible, both chambers should be cannulated and that they should be connected together to the stopcock through a T-junction. As a result the anterior chamber appeared to maintain its normal depth during the course of the experiments and the results fell between those obtained if each chamber was cannulated separately. Only results from eyes with double cannulation, then, were accepted for the calibration of the instrument.

To cannulate the anterior chamber, a very fine needle (0·3 mm. outside diameter) was pushed through the sclera into the posterior chamber and then directed forwards behind the iris until its point appeared in the centre of the pupil. It was connected to the manometer by a loop of very fine polythene tubing drawn down from the smallest available commercially. The end of the tubing was fitted directly over the shank of the needle which was separated from its syringe mounting. The vitreous cannula was a large-bore serum needle connected to the manometer by means of polythene tubing fitted over its shank. It was pushed squarely through the sclera at the outer canthus. Free connexion with the vitreous humour was established by aspirating about 2 ml. of it and replacing it with saline; this was made easier by drilling some small holes through the wall of the needle near its tip.

The procedure was as follows. The zero of the manometer scale was carefully levelled on the apex of the cadaver cornea by means of an arm carrying a spirit-level, and the reservoir was set to a level of 30 cm. saline. The stopcock was turned to allow a slow drip to escape and the vitreous and aqueous humours were cannulated and connected to the T junction, care being taken to avoid the introduction of air bubbles. The tonometer was mounted on the forehead of the cadaver in the normal manner and the foot adjusted on the cornea. The manometer was then set to the lowest calibration pressure, 10 or 15 cm. of saline, and the stopcock opened fully. The plunger was brought into contact with the cornea and advanced 0·5 mm. into the eye as in a normal

reading. When the output was steady the open stopcock reading was taken.

Two series of closed stopcock readings were made: one in which the rise in pressure was caused by the indentation of the plunger alone and the other by the plunger and foot together. In the first series, the foot of the instrument rested on the cornea while the eye was in open connexion with the manometer for about one minute to allow pressure equilibrium to be established. The plunger was brought into contact with the cornea, the stopcock was closed, and plunger was immediately advanced 0·5 mm. The reading usually underwent a sharp fall of undetermined cause in the first second and then a more gradual one. The closed stopcock value was taken to be that immediately after the initial fall. In the second series, the plunger was brought into contact with the cornea and then the foot was lifted off the eye for one minute with the stopcock open. The plunger was advanced 0·5 mm., the stopcock was closed, and the foot was dropped onto the eye. The maximum reading was recorded and accepted as valid if the plunger contact position was correct on checking.

Open and closed stopcock measurements of both sorts were interspersed with one another until at least three of each were obtained. The pressure in the eye was then raised and the process repeated. This was continued until a pressure of 80–90 cm. of saline was reached. A few readings were taken on the return to lower pressures but they did not differ from those taken before the eye was subjected to high pressure. At the end of each calibration the relationship between tonometer reading and plunger force was checked on the balance.

Seven eyes of six cadavers, obtained 5 to 22 hours after death, were treated in this way. They aged from 42 to 82 years at death and their case histories were free of ocular trouble. No trends with age or delay after death were found in this small sample. The open stopcock measurements, one of which is shown in Fig. 13 (opposite), all gave similar results. The points lie closely on a straight line until a pressure of 70 cm. saline (50 mm. Hg) is reached. These lines pass slightly above the origin, cutting the ordinate at a mean value for the seven eyes of 0·35 g. with a standard deviation of 0·21 g. The average slope of the lines is 0·093 g/cm. saline (0·125 g./mm. Hg) with a standard deviation of 0.0083 g./cm. saline (0·011 g./mm. Hg). The variation between the individual lines is believed to result from a real difference, of undetermined origin, between the eyes and not from instrumental uncertainties.

Above 70 cm. saline the calibration ceases to be linear, the points falling more and more below the line as the pressure rises. This is in great part because the residual force on the foot, less than 3 g. at these pressures, is insufficient to keep it in good contact with the cornea. When the tension on the control spring was raised to a value of 15 to 20 g., the experimental points obtained at high pressures fell closer to the straight line but lay below it still. The cause of the residual non-linearity is the flexibility of the stylus of the transducer valve. Under the maximum force encountered in the calibration,

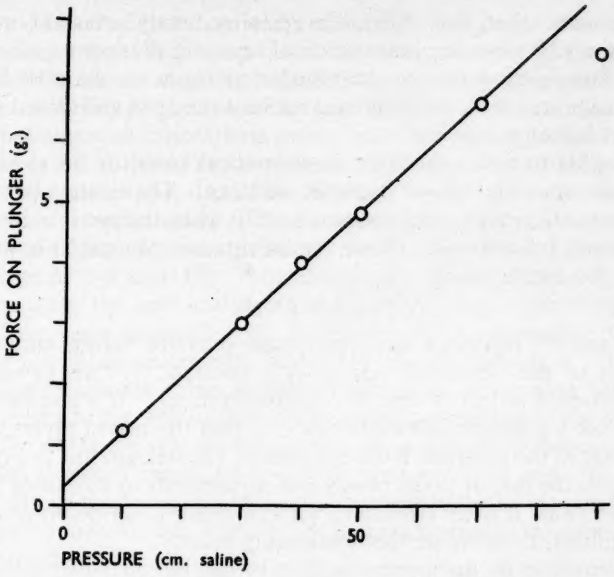


FIG. 13.—Open stopcock calibration. Points from one eye.

8 g., the tip of the stylus may be calculated to deviate by almost 0.05 mm. Accordingly, the indentation of the cornea by the plunger at high pressures will be reduced by this amount, almost 10 per cent of its nominal value.

The closed stopcock measurements were invariably higher than the open. Fig. 14 shows the average and range of the difference between their values.

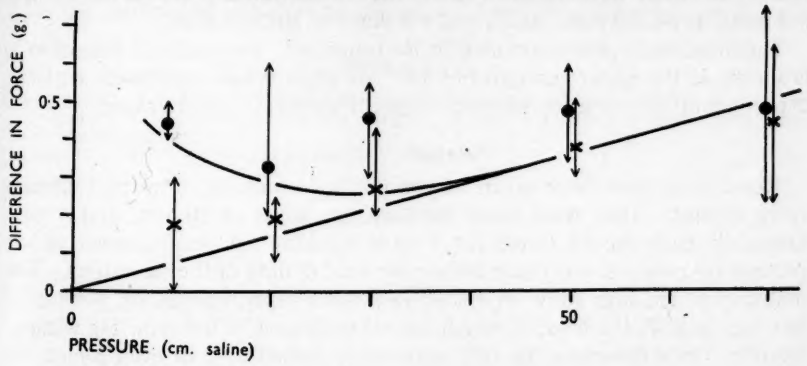


FIG. 14.—Closed stopcock calibration. Mean values and ranges from five to seven eyes.
Abscissa: Pressure in eye before indentation, P_0.
Ordinate: Difference in force on plunger between closed and open stopcock measurements.
Circles: Indentation by foot and plunger together.
Crosses: Indentation by plunger alone.
Curves derived theoretically as explained in text.

It will be seen that this difference remains nearly constant at 0·5 g. whatever the IOP when the indentation of foot and plunger together is considered. The fraction due to the plunger increases as the IOP rises and virtually accounts for all the difference between the open and closed stopcock readings at higher pressures.

It is possible to find a quantitative theoretical basis for the experimental values of the open and closed stopcock readings. The relation put forward by Friedenwald (1954) for the increase in IOP when the eye is indented by a tonometer will be assumed. When the indentation volume V_T is very small this takes the simple form:

$$P_T - P_o = KV_TP_o \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where P_o and P_T represent the intra-ocular pressure before and after the application of the tonometer and K is a constant. From Friedenwald's determinations, K is $0{\cdot}0215 \times \log_e 10$, or 0·05 per mm.^{3}. It is assumed that the plunger gives a constant indentation, V_I, so that the rise in pressure will be proportional to the pressure in the eye itself. The straight line in Fig. 14 was drawn to give the best fit to the points and corresponds to a value of 1·5 mm.^{3} for V_I; this value is quite consistent with an indentation depth of 0·5 mm., but it is difficult to calculate the relationship exactly.

The indentation by the tonometer foot V_F can be calculated to be:

$$V_F = \frac{2}{\pi^2 9\sqrt{3}} \left(\frac{F}{RP_T}\right)^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where F is the force pushing the foot on the eye and R is radius of the cornea. F must be put equal to 10 g. less the force on the plunger derived from the open stopcock calibration. From these equations it is possible to calculate the total indentation V_T, at any value of P_o. Actual values are 8·5 mm.^{3} at 10, 3.0 mm.^{3} at 20, and 1·8 mm.^{3} at 30 cm. saline.

The total rise in pressure caused by the tonometer, derived from Equation 1, is shown as the upper curve in Fig. 14. Its approximate agreement with the experimental points lends support to this theoretical interpretation.

Normal Values

Recordings have been taken of the IOP of a number of normal subjects lying supine. They were made between the hours of 10 a.m. and 4 p.m. Generally each record lasted for 5 or 6 minutes. A readjustment of the plunger indentation was made before the final minute of the recording. The majority of tracings show rhythmic variations superimposed on a more or less steady IOP, the level of which can be estimated to 0·5 mm. Hg without trouble. In a few cases the IOP apparently drifted by 2 or even 3 mm. Hg in the final period and there is a corresponding uncertainty in assigning it a value. The mean value of the pressures from 22 subjects estimated in this way was 19 mm. Hg, with a standard deviation of 3 and extremes of 15 and 26 mm. Hg.

It should be noted that these levels are measured at a time when the IOP has returned to normal after being raised by the application of the instrument. Unlike determinations made with the Schiötz tonometer they are independent of the distensibility of the eye. The conditions were comparable with those of the open stopcock calibrations except that there may have been differences in the flexibility of the cornea as a result of *post-mortem* swelling.

The total tonographic drop was measured as the difference between the value at the first indentation of the plunger and the final level achieved after the depth of indentation was checked. It had a mean value of 3·5 mm. Hg and a range of 1–8 mm. Hg. This drop might be expected to be similar to the difference of the open and closed stopcock readings if the living and dead eyes had the same distensibility. Normally the foot is resting on the subject's eye for about one minute before the plunger indents it. The appropriate closed stopcock value, therefore, should be somewhere between that corresponding to the application of the whole instrument to the eye and the indentation of the plunger alone. The average differences between the open and closed stopcock readings at a mean pressure of 19 mm. Hg are 4 and 2·5 mm. Hg in the two cases, in fair agreement with the tonographic drop. The range is much smaller, but since only seven cadaver eyes were tested it is of little significance.

As was stated previously the pulse pressure amplitude varies greatly from eye to eye and is not constant for one eye during a recording. A rough value can be assigned in each case however and in this sample of eyes, the peak to peak amplitude varied from 0·5 to 2·5 mm. Hg (mean 1·5 mm. Hg).

I wish to thank Mr. C. J. Downing for constructing this instrument, and Mr. F. Sheen for making a prototype. Mr. W. E. S. Bain kindly assisted with the calibration and the recordings.

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EYE DISEASES IN AFRICAN CHILDREN*

WITH SPECIAL REFERENCE TO ONCHOCERCIASIS AND *MALNUTRITION*

BY

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In the course of a recent Ophthalmic Survey in Africa, an opportunity was afforded of examining the eyes of children in Ghana, Nigeria, and the Cameroons. Our activities took us from the rain forests to the northern semi-desert frontiers of the territories concerned. We have records of 618 children in a sample of 5,000 blind. Many more (510) suffering from eye disease were also examined. The paper will be divided into four sections: the commonest causes of blindness, other common eye diseases, onchocerciasis, and ocular manifestations of malnutrition.

I. The Commonest Causes of Blindness

One is forced to conclude that there is a greater risk of an ocular ailment progressing to blindness where the nutrition is poor. It is perhaps for this reason, then, that measles and chickenpox are amongst the most common of all conditions leading to blindness. That secondary infection is not altogether part of the picture is a belief strengthened by the fact that after corneal rupture the ocular lesion usually settles down quickly, leaving behind a quiet leucoma adherens, often bilateral. The same sort of picture occurs in smallpox, although a greater number of smallpox cases occurs among the older age groups.

In the break-down by age groups, 20 per cent. of the children in the 0 to 5-yr group, 13 per cent. in the 6 to 10, 12 per cent. in the 11 to 15, and 8 per cent. in the 16 to 18-yr group had been blinded by measles; this underlines the fact that it is the small children who are particularly affected. In the case of smallpox, though 8 per cent. of all the blindness we found was caused by this disease, every case lay in the 10 to 18-yr group. The explanation may be that when small children are attacked by smallpox they seldom survive. In one village we visited, of sixty deaths from smallpox, one-third were in children under 15. Our belief that poor nutrition, especially avitaminosis A, plays a part in expediting blindness from specific fevers is strengthened by the fact that, in the 0 to 10-yr group, 14 per cent. of the children had double lesions, and in every case this was an admixture of a

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measly eye with xerosis corneae. The same thing to a slightly less extent was seen in the 11 to 15 group, whereas in the 16 to 18 group two-thirds of the double lesions resulted from the association of trachoma with either smallpox or onchocerciasis depending on the locality; xerosis corneae accounted for only a few cases.

Trachoma, when endemic, is perhaps the greatest single cause of blindness in African children. We frequently observed in the young a fulminating type, not hitherto described, which led to total opacification of the cornea within a year or two (Fig. 1). The clinical picture was a classic one inasmuch as it was almost entirely in this type that trachoma follicles were observed. In children suffering from this fulminating variety, an invariable accompaniment is a gross migration of chromatophores into the palpebral conjunctiva, so that pigment covers the follicles. If it were not for the characteristic corneal pannus the condition would simulate acanthosis. We have called this type trachoma nigricans. In general, active trachoma was restricted to children up to 5 years of age.

FIG. 1.—Pannus trachomatosus.

Corneal ulceration is not so common a cause of blindness as one might think; in the age groups we recorded, blindness from ulceration accounted for about 3 per cent. in each. A muco-purulent conjunctivitis caused by the Koch-Weeks bacillus cannot really be related to corneal ulceration; 16 per cent. of the non-blind children in the 0 to 5-yr group, 20 per cent. in the 6 to 10, 10 per cent. in the 11 to 15, and 3 per cent. in the 16 to 18-yr group were so infected, yet in none was there evidence of corneal ulceration,

although one showed an unhealthy margin. We seldom found blennorrhoeas in infants due to the gonococcus; only one proven case was seen, all the others being apparently inclusion-body blennorrhoeas. A not infrequent end-result of the latter is the appearance of a large conjunctival granuloma of the upper lid. The corneae were never damaged.

Phlyctenulosis is particularly common in the children of North Nigeria, and we occasionally found sclerosing keratitis, almost certainly tubercular.

The interstitial keratitis of congenital syphilis was only rarely seen, and this manifestation is more common in acquired syphilis. Xerosis of the cornea and keratomalacia will be described in Section IV. Trauma is the chief cause of unilateral blindness, thorns and branches being the main offenders, which is not surprising in view of the fact that small boys act as herdsmen, walking through the bush in charge of the cattle.

Tumours of the eye are not common in African children; in the entire series of 1,128 we recorded only three, two being melanomata of the choroid and one a retinoblastoma.

Uveitis is not much seen in children, although wherever we visited an area that had in the past suffered from an epidemic of cerebrospinal meningitis we were sure to find a few children blinded by a meningococcal anterior uveitis. This condition appears to be invariably accompanied by total occlusion and the occluding membrane is characteristically very heavily pigmented; in three-quarters of our cases, moreover, the condition was associated with deafness.

Optic atrophy was sometimes seen in the young, but its origin was nearly always obscure. It was seen in a few cases of recovered cerebrospinal meningitis, but we tend to the belief that it is often part of a syphilitic basal meningitis; it was almost always accompanied by a divergent strabismus, suggesting involvement of the abducent nerve. Whenever serological tests were carried out on such optic atrophy cases, they proved positive.

Congenital cataract was found in only one child throughout the entire survey.

II. Other Common Eye Diseases

In case the wrong impression is given, it must be stressed that blindness does not always follow such conditions as trachoma and the specific exanthemata. By far the majority of cases are seen with only a slight residual defect of vision. One in four children examined with the biomicroscope in villages where trachoma is endemic will exhibit a mild degree of pannus trachomatosus, which shows that this disease is not always disastrous. An orbital cellulitis is a fairly frequent finding in children, and vernal catarrh is also seen from time to time, being frequently accompanied by a marked chemosis of the limbus, the pigment of which often invades the entire periphery of the

cornea for a few millimetres. Buphthalmos was seen in a child suffering from congenital hydrocephalus. Nystagmus was rare and the cause difficult to decide. However, in two cases in small children, both under 6 years of age, serological tests were performed, and as the results were positive, it was thought that syphilis was responsible for the condition. We were unable to confirm this by therapeutic tests because the parents refused to allow treatment.

The use of native medicine is without doubt widespread; it is often applied as an instillation before the child is brought to the hospital, and exactly how far this is responsible for blindness, one cannot be certain. It is perhaps sufficient to say that some proven cases are on record; the majority, however, despite badly scarred corneae, usually retain some visual acuity. Antimony and lead adornments to the eyelashes are often forced by doting fathers on their sons and daughters, and are a frequent cause of an irritant conjunctivitis. Embedded foreign bodies, usually the seeds of plants, were not as common as might be expected.

Virus diseases (in addition to smallpox and trachoma) are perhaps the lesions most commonly discovered among the non-blinding eye diseases of African children. Herpes febrilis after an attack of malaria is very common, as is the epidemic adenoid kerato-conjunctivitis found in the schools. As a generalization, 25 per cent. of young Africans may be said to exhibit a punctate keratitis due to these two viruses. The classic dendritic ulcer of herpes corneae was never seen in children. Just as rare is ocular leprosy, for mercifully this disease is being controlled more effectively every year. We saw an infiltrative lepromatous keratitis on a few occasions only.

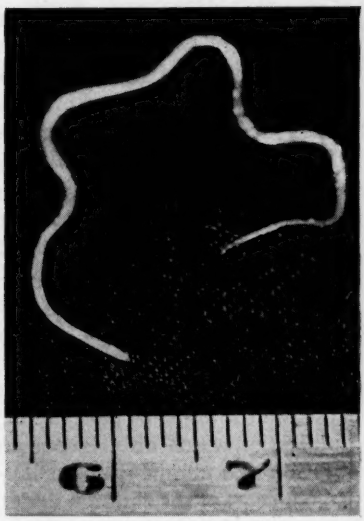

FIG. 2.—Adult *F. loa*, female, 64 mm. long, removed from the eye of a young male nurse aged 18.

In the high forest belt, the infestation of children with *F. loa* is fairly frequent, and we removed one female adult 64 mm. long from the eye of a youth who was a nurse (Fig. 2).

III. ONCHOCERCIASIS IN CHILDREN

The youngest child we found infected with onchocerciasis was a little girl of 4 years. As might be expected, the older the child grows, the more

liable it is to acquire the disease, the critical age being around 10 years in heavily endemic areas. The following figures, being a breakdown in age groups from 1 to 20 years, were obtained in Northern Ghana:

Age Group (yrs)	5 and Under	6–10	11–15	16–18	19–20	Over 20
Percentage	2	37	65	78	91	100

The older age groups are added for comparison. Thus, in a heavily infected area, approximately one-third of the children under 10 years of age suffer from the disease.

The mean Individual Density Figure for children in this region of Ghana was eighteen (Rodger and Brown, 1957).

In this earlier communication an eight-skin biopsy series, repeated if necessary to a maximum of sixteen, was recommended, but we restricted the series to a maximum of twelve in the case of children. The chance of missing an infected site after taking four skin biopsies, as is shown in the paper referred to above, is only 1 in 256, so it would seem that not many cases, if any, were missed in the group of children from which these statistical deductions were taken. The infectivity rate for children under 6 years of age (2 per cent.) is much higher than that reported by most other workers, although the number of biopsies done by them was not always the same; the babies frequently objected strongly and the infectivity rate may be even higher than that found.

Of the children under 10, 9 per cent. had palpable nodules; of these, 58 per cent. were on the head, which is a most interesting finding, as in Africa head nodules in adults are rare. It may be related to the fact that babies are slung on their mother's backs in a blanket, their heads alone being exposed. The remaining nodules found in children were evenly distributed between the chest and the hip. 24 per cent. of those aged between 10 and 18 had palpable nodules, of which only 19 per cent. were on the head, suggesting that the duration of a nodule is about 10 years (Fig. 3, opposite).

6 per cent. of the children under 10 with nodules had sterile skins, but only 2 per cent. of those between 10 and 18 years. 3 per cent. of those under 10 had positive skins without any palpable nodules, 14 per cent. between 10 and 18. In the early stage the nodule appears as a small, hard, discrete lump, apparently only loosely attached to the underlying fascia. When found at or near the mastoid process or occiput, they were sometimes confused with glands. We excised and examined several such, and in each case adult worms were present; they were true onchocercomata.

One per cent. of the children under 10 years of age exhibited positive conjunctivae; 1 per cent. also were positive in the 10 to 18 age group; 2 per cent. of those under 10 with positive conjunctivae, and 3 per cent. of those between

10 and 18, had negative skin biopsies. The samples from which all these figures were taken, of course, came from cases selected on account of some visual disorder, so these percentages may be high. In a random sample of 100 children without ocular complaints, none of the conjunctivae was positive.

FIG. 3.—Youth aged 17 in the late stages of trypanosomiasis, also suffering from onchocerciasis. Onchocercomata may be seen over the chest and hip.

Whatever the figures may imply, the importance of carrying out conjunctival biopsies in children with negative skins must be evident.

Several samples were taken, not only to obtain infectivity rates in groups of 100 children but also to assess the increased risk of infection in geographical relation to the endemic area (Table I):

TABLE I
INFECTIVITY RATES

Subjects	Age	Area	Percentage
(1) Village children	Under 18	Endemic area	57
(2) Village children	Under 18	Edge of endemic area	12
(3) Village children	Under 18	About 50 miles from the nearest known endemic area	Nil
(4) School children	Under 18	In school at edge of endemic area	7
(5) School children	Under 18	In school well outside endemic area, but children spent 3 months' holiday within an endemic area in their own villages	3

Ocular onchocerciasis was observed in many children under the age of 10 in the series. In some of them double lesions existed. The distribution is shown in Table II:

TABLE II
DISTRIBUTION OF ONCHOCERCIASIS

Condition	Subjects	Age	Percentage
(1) Punctate corneal opacities	Village children, none of whom suffered from onchocerciasis	Under 18	19
(2) Punctate corneal opacities	Children of same villages suffering from onchocerciasis	Under 18	9
(3) Punctate corneal opacities	Non-infected resident schoolboys	Under 18	41
(4) Punctate corneal opacities	Same suffering from onchocerciasis	Under 18	3
(5) Onchocercal punctate opacities with early pannus			2
(6) Onchocercal "limbitis" (kerato-sclero-conjunctivitis)			3
(7) Onchocercal anterior uveitis			2
(8) Optic atrophy associated with onchocerciasis but of obscure origin			0·5
(9) Posterior uveal lesions			Nil
(10) Occlusion of the pupil in (7) above			14
(11) Partial occlusion of the pupil in (7) above			14
(12) Complicated cataract in (7) above			20

The specified incidence of corneal opacities given in Items 1 to 5 above further strengthens the belief expressed in another paper (Rodger, 1957) that punctate corneal opacities are not necessarily a manifestation of onchocerciasis. For every case due to onchocerciasis we believe there will be two due to the adenoid viruses, and three to the herpes virus even in an endemic area. If we exclude punctate keratitis, 3 per cent. of the children under 10 years of age and 15 per cent. of those between 11 and 18 suffered from severe ocular onchocerciasis. From the data we possess, it is difficult to say what percentage of all children with onchocerciasis become afflicted with its ocular manifestations; the most reliable information we have is that, in 45 (15 per cent.) of 300 children under 18 years of age in a heavily endemic region all with painful or blind eyes, the cause was onchocerciasis. The figures are too small to take the matter further, but it should be noted that in the region concerned there was little trachoma.

In conclusion, a few generalizations may be of interest: in a heavily endemic area it can be expected that one-third of the children under 10 years of age will be infected with onchocerciasis. In one-tenth of these, palpable nodules will be found; these nodules will be small and hard and are as likely to be found on the head as on the trunk. It should not be surprising if in those with nodules skin biopsies prove negative. One in a hundred of children under 10 years of age in an endemic area may have positive conjunctival biopsies, usually unilateral, and usually associated with a head nodule; the skin biopsies again may be negative. When we consider children of the older age groups, 10 to 18 yrs, the nodules on the trunk will be found to have grown larger, while the head nodules may have disappeared; it will be unusual to find any nodule in the absence of a positive skin in this group.

As for eye disease in a heavily endemic onchocerciasis area, of 100 children with ocular lesions from any cause, in three of those under 10 and in fifteen in the 11 to 18-year age group it will be due to onchocerciasis. The most common manifestation of onchocerciasis in the eyes appears to be a chronic conjunctivitis affecting the limbal tissue with an associated opacification of the adjacent sector of cornea; the site of this disorder is the lower half of the limbus, and is characteristic of the disease; punctate opacities may be associated. In almost the same number of cases the lesion will affect the iris. The majority of the latter will be blind. It is most unlikely to find chorio-retinal lesions in the young, and for the occasional case of optic atrophy a cause other than onchocerciasis should be sought.

IV. Ocular Manifestations of Malnutrition

Whenever vitamin deficiencies are discussed, it is always stressed that in practice these deficiencies are invariably multiple. In West Africa this is not really true. In the northern territories of the countries we surveyed there is a considerable deficiency in vitamin A, a deficiency in protein, and a slight deficiency in riboflavin, the daily consumption amounting to three-quarters of the international requirement; at first sight this would seem to be perfectly adequate for people on a low calorie diet; however, a naso-labial seborrhoea, sign of a mild deficiency, was widespread.

We did not find in any children evidence of nutritional amblyopia. We did see an occasional case of optic atrophy, some of which theoretically might have been due to a deficiency in the vitamin B complex, but none was characteristic. Our own view (Rodger 1953, 1954) is that an optic atrophy develops only when a deficiency of thiamine is prolonged, a state of affairs that is accentuated when riboflavin is also deficient. That there was in these parts no deficiency in thiamine, and no nutritional amblyopia, supports this belief.

Our interest in malnutritional defects of vision rests almost entirely, therefore, on a deficiency in vitamin A, which was general. We found very few

cases exhibiting Bitot's spots. Appelmans, Lebas, and Missotten (1956) have shown that Bitot's spots can appear in well-nourished subjects; this was our experience also. We found them irreversible, a fact not previously appreciated (Fig. 4).

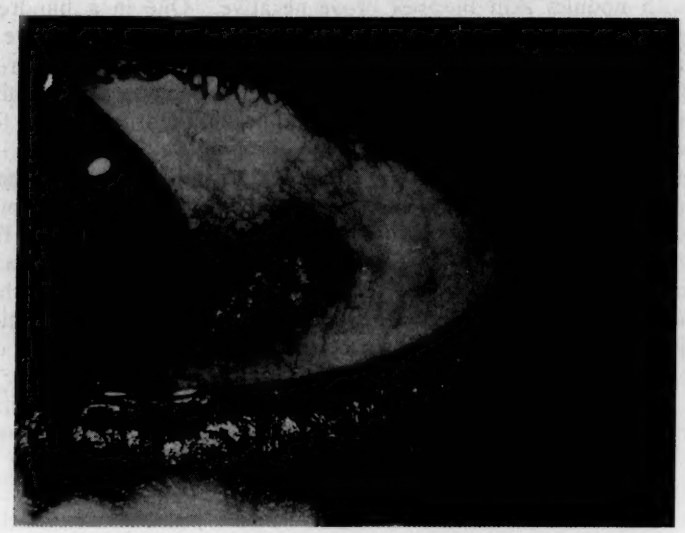

FIG. 4.—Bitot's spots (proven histologically) in an 18-year-old African clerk. This was irreversible.

In view of these observations, it is doubtful whether much credence should be placed in the theory that Bitot's spots are evidence of vitamin A deficiency. Extremely common, on the other hand, was the appearance of whipped-up clear mucus in the outer canthus; this was reversible. It was often seen in association with brown pigmentation of the bulbar conjunctiva and folds in that tissue, the two latter signs, according to Pillat (1933), being undoubtedly due to avitaminosis A. Collectively this triad of signs should in our view replace Bitot's spots as evidence of an incipient xerophthalmia.

Xerosis corneae (Fig. 5, opposite) going on to keratomalacia was very common indeed among African children. As indicated in an earlier part of this paper, these two conditions frequently tilted the scales adversely where the eye was attacked by a pathogenic agent. The classic examples of this are measles and phlyctenulosis. Blumenthal (1950) described seven varieties of what he called malnutritional kerato-conjunctivitis. In our view, all of these may be laid at the door of avitaminosis A, in some instances associated with a primary or a secondary infection. In very young children the most common appearance of keratomalacia was a thinning of the cornea resulting

FIG. 5.—Unusual formation in xerosis corneae. The central lesion lies in the epithelium. The marginal pigmentation and folding of the bulbar conjunctiva can just be made out. The whole eyeball was dry. It is surrounded by pigment.

in a clean prolapse of iris; it was characterized by the complete absence of an inflammatory reaction (Fig. 6).

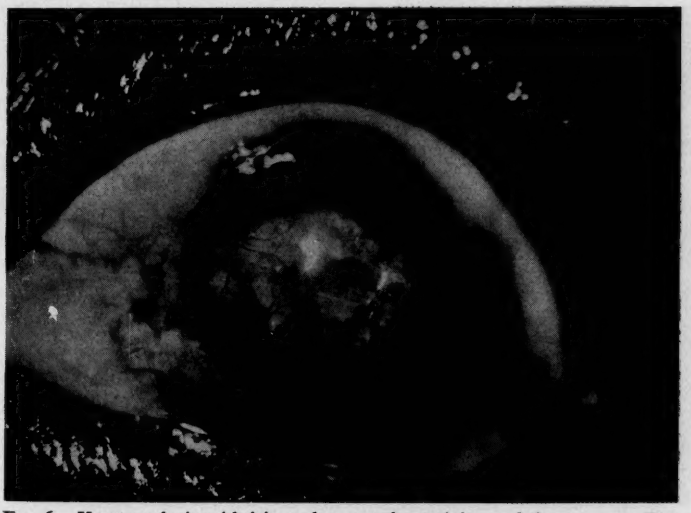

FIG. 6.—Keratomalacia with iris prolapse at the periphery of the cornea. This child had been treated by the native *malam*, and the gross scarring in the lower fornix (due to the medicine), which complicates the picture, is characteristic.

These children did not appear to suffer at all. One can only assume that the corneal nerves atrophied with the cornea. Secondary infection alone, perhaps, is what alters the clinical picture. After cauterization with trichloracetic acid, the administration of massive doses of vitamin A soon causes this condition to heal and the thinning to stop.

In an advanced xerosis (in older children), the cornea is hypoaesthetic and lacks its usual lustre. We did not see the punctate corneal opacities described by Appelmans, but a crescent-shaped white opacity passing from or near the limbus was a common sight. Isolated polyhedral corneal opacities about 5 mm. across appeared in the more severe cases and sometimes became confluent. When as a result of keratomalacia the opaque cornea became thin, they usually perforated without any sign of ulceration. As a result of secondary infection some of the eyes went on to panophthalmitis; in others a central leucoma adherens was formed.

In association with both xerosis and keratomalacia, epithelial scrapings revealed massive numbers of *Corynebacterium xerosis*.

Night blindness in children, as might be expected, was extremely common. It was readily reversible with about 100,000 i.u. vitamin A orally after 5 days. The improvement usually progressed over the next week or so without further treatment and was maintained for several months. An interesting point is that there appears to be no constant association of any one of the classic manifestations of avitaminosis A with any other. For instance, one seldom found xerosis or keratomalacia combined with night blindness. It may well be that, in the case of one or other, another factor is present. The triad of signs we describe as pre-xerosis on the other hand was invariably seen with both types of disorder.

Summary

(1) The commonest causes of blindness in African children are trachoma, measles, smallpox, keratomalacia, and phlyctenulosis, in that order.

(2) A new (fulminating) type of trachoma in children is described. It has been called trachoma nigricans.

(3) The most common non-blinding eye disease seen was a virus punctate keratitis, followed by muco-purulent conjunctivitis.

(4) In a heavily endemic onchocerciasis area, the first sign of the disease in the child will be a nodule usually on the head; this even in very young children may be associated with invasion of the eyes, but is often unassociated with invasion of the skin.

(5) In a heavily endemic area, 3 per cent. of children under 10 years of age were found to suffer from ocular onchocerciasis. The most common lesions were a "limbitis' (kerato-sclero-conjunctivitis) and an anterior uveitis.

Occlusion of the pupil in the latter was the commonest single cause of blindness due to onchocerciasis in children.

(6) Vitamin A deficiency can cause hemeralopia, pre-xerosis, xerosis itself, and keratomalacia; they were each found in African children although not *necessarily in association one with the other.*

(7) Keratomalacia, characterized by spontaneous iris prolapse without an inflammatory reaction or painful symptoms, is perhaps the most typical and striking of all the appearances of avitaminosis A in small children.

(8) Whipped-up clear mucus in the outer canthus, conjunctival pigmentation *especially close to the limbus, and folds in the bulbar conjunctiva* constitute a triad of signs indicative of pre-xerosis. It appears to be much more significant than Bitot's spots.

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CORRIGENDA

The following corrections should be noted in "Posterior Degenerative Lesion of Onchocerciasis", by F. C. Rodger, *Brit. J. Ophthal.* (1958), **42**, 21:

p. 23 (b), last line: for "in onchocerciasis" read "in onchocerciasis areas".
p. 26 (footnote): for "Dr. M. Giagiunto" read "Dr. M. Giaquinto".
p. 28 (Table II): delete records of serial numbers 772 and 837.
p. 29 (Table III, footnote): for "cod liver oil" read "vitamin A".
pp. 33 and 34: for "Ramingalaswami" read "Ramalingaswami".

Brit. J. Ophthal. (1958) **42**, 348.

SWELLING OF THE RAT *RETINA INDUCED BY METABOLIC* INHIBITION*

BY

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ASHTON, Graymore, and Pedler (1957) tentatively suggested that external pressure may be a causative factor in vaso-obliteration, as observed in the kitten retina following the intravitreal injection of sodium iodoacetate or sodium fluoride. They commented upon the possibility that treatment by such established metabolic inhibitors, by denying the cells the energy they normally derive from carbohydrate catabolism, might lead to a breakdown in the mechanism responsible for regulating cell size.

Opie (1949) was the first to observe that certain tissues, after isolation from the rat, imbibed fluid unless they were bathed in solutions which were distinctly hypertonic. This apparent hypertonicity of such cells to their natural environment, could be effectively abolished by certain toxic agents (Opie, 1950). Other workers have since confirmed this phenomenon in tissues such as liver, kidney, spleen, and brain, and have concluded that there is some definite relationship between cell size and the efficiency of the energy metabolism of the cell. Isolated tissues, even in a balanced saline medium, have been observed to swell under a variety of conditions leading to a reduced efficiency in energy production or capture (Stern, Eggleston, Hems, and Krebs, 1949; Aebi, 1950; Robinson, 1950a, b).

This work led to the concept that living cells were not in osmotic equilibrium with their environment, and that their osmotic pressure was maintained at a higher level, as a steady state, by a process drawing on metabolic energy to pump water outwards through the cell membrane. This hypothesis and the experimental evidence which led to its formulation have been adequately reviewed (Robinson and McCance, 1952; Robinson, 1954).

In the light of the suggestion of Ashton and others (1957) that retinal swelling induced by iodoacetate and fluoride may conceivably be a causative factor in vaso-obliteration, it was thought that it would be worth while investigating the *in vitro* effect of these inhibitors on the imbibition of water by the rat retina, to determine whether this phenomenon does, in fact, occur in retinal tissue.

Method and Materials

Variations in the water content of isolated rat retinae were determined after incubation with and without iodoacetate or fluoride. The water content was

* Received for publication July 16, 1957.

assessed by calculating the wet-weight:dry-weight ratio of the tissue at the end of the period of incubation.

Animals.—The animals used were female albino rats aged about 3 months and weighing 180–200 g.

Incubation Medium.—*A standard Krebs-Ringer-bicarbonate buffer was employed (Krebs and Henseleit, 1932), the solution being gassed throughout with 5 per cent. CO_2–95 per cent. O_2. 200 mg. per cent. "analar" glucose was added as substrate. For the preparation of tissues this buffer was chilled in ice.*

Iodoacetate.—Iodoacetic acid was recrystallized from a sample obtained from British Drug Houses and was neutralized before use. The final concentration employed in the flask was 0·001 M.

Sodium Fluoride.—*This was also obtained from British Drug Houses and was used in a final concentration of 0·01 M.*

Both solutions were made up in such a concentration as to necessitate the addition of 0·1 ml. to the experimental flasks. 0·1 ml. of glass-distilled water was added to the control flasks.

Removal and Weighing of the Retina.—*In order to obtain results of sufficient accuracy to be able to detect small variations in the water content of the tissue by simple weighing procedures, two conditions must be fulfilled:*

(1) Removal of the retina should be accomplished rapidly, involving as little cellular fragmentation as possible. Ideally, the retina should be removed in its entirety. This will minimize irreversible changes in the metabolic pattern.

(2) A technique must be devised which will minimize errors inherent in the weighing of small quantities of tissue. The fragility of the retina is a complicating factor in both these procedures.

(*1*) *Removal of the Retina.*—Several recognized procedures were tried, but that to be described was developed in this laboratory and found to be the most effective. In view of its wide application this will be presented in some detail.

After enucleation, the eyes were transferred to a small plastic cutting block (Fig. 1, overleaf). A convenient block measures 6 × 3 × 0·5 cm. A series of pits of suitable dimensions was drilled in the surface. Those in the block used in the present investigation had diameters ranging from 3 to 6 mm. and their depths lay within the limits 1 to 3 mm. A fine drainage canal was drilled through to the base of the block from each well.

The eyes were placed anterior surface upwards, in a well having the appropriate dimensions, such that half the eye was exposed above the block, the posterior aspect of the eye fitting snugly into the pit. The eye was held in place by a plastic strip possessing a suitably proportioned hole at one end, allowing a firm grip over the cornea. Ideally the eye should be situated as shown in Fig. 2 (overleaf). The eye was cut through the equator by means of a sharp flat razor blade inserted between the block and the holder. In the position shown in Fig. 2, a blade applied along the surface of the block will section the eye immediately behind the ora serrata, the retina will then be freed from the choroid anteriorly, and its only remaining point of attachment will be around the optic disc.

The posterior "cup" of the sectional eye was then removed into a shallow vessel containing the appropriate chilled buffer, and the "cup" was inverted. The vitreous, if still adherent to the exposed retina, was removed with forceps. At this stage, the retina "parachuted" out from the inverted cup of the choroid, and a single cut across the posterior point of attachment at the optic disc freed it completely.

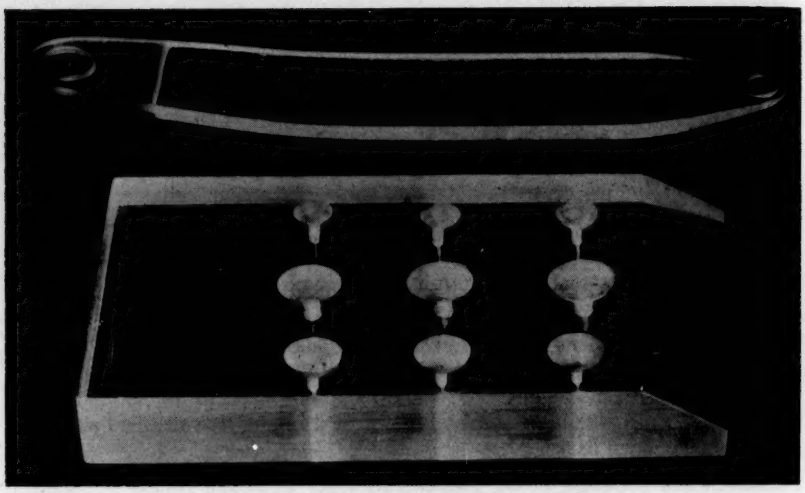

FIG. 1.—Plastic holder (A) and block (B) described in text.

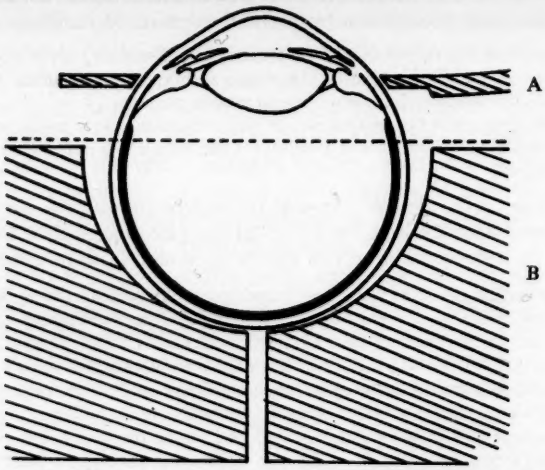

FIG. 2.—Diagrammatic representation of an eye being held in position by the holder (A) in one of the wells of the block (B). The broken line indicates the position through which the blade should pass.

The whole procedure, from the time of killing the animal to the final isolation of the retina, should occupy no more than 1 to 2 minutes.

(*2*) *Weighing*.—Conventional methods cannot be applied so readily to the retina. The tissue is remarkably fragile and any attempt to dry the excess moisture from its surface by the accepted technique of light mopping with filter paper will result in the tissue adhering to the paper. The following method overcame these difficulties and provided an accurate and rapid means of weighing.

Small squares of filter paper (Whatman No. 50) were prepared having the approximate measurements 5 × 5 mm. The simplest procedure is to cut these simultaneously from a block of paper, thus ensuring a reasonable uniformity of size. (A cork borer was also found to provide a convenient cutting tool which would yield discs of paper of matching size.)

These papers were immersed in the buffer to be used, and were placed on a large flat filter paper for 15 seconds, care being taken to ensure adequate contact. Preliminary experiments had revealed that this treatment was sufficient to drain away all excess buffer from the papers and that under these conditions the papers retained exactly the same proportion by weight of the buffer. The percentage loss of weight of these papers was determined after 2 hours heating at 110° C. This was found to be constant.

To weigh the tissue, the retina was removed from its medium and laid flat on a square of paper which had been previously weighed after saturating with buffer as above. The paper was transferred to the drying sheet for 15 seconds, and re-weighed. The wet-weight of the retina was obtained by subtraction. The retina plus paper was then dried for 2 hours at 110° C., and the dry-weight of the retina was calculated taking into account the weight loss of the paper. Excellent reproducibility was obtained by this method.

General Procedure.—Animals were killed by dislocation of the cervical vertebrae and the eyes were enucleated as rapidly as possible. The retinae were removed as described and transferred to square Warburg flasks, containing 6 ml. ice-cold gassed incubating medium, to which had been added sodium fluoride, sodium iodoacetate, or glass-distilled water. The flasks were attached to their manometers and gassing with 5 per cent. CO_2–95 per cent. O_2 was continued. They were incubated for one hour at 37° C. Shaking was somewhat slower than that normally employed (70 per minute) to preserve the integrity of the tissue as far as possible. At the end of the period of incubation the retinae were carefully removed and their wet-weight and dry-weight were determined as described.

Time-Course.—In the experiments designed to test the rapidity with which iodoacetate-induced swelling occurs, all retinae were incubated in normal medium for 30 minutes before zero time. Some retinae were then removed and their ratios determined, whilst iodoacetate was added to the remainder. This served to eliminate transient changes which might arise as a result of removing the retina, immersing in chilled buffer, etc. Iodoacetate-treated retinae were then removed at the time intervals indicated.

Results and Discussion

Results were calculated as the ratio Wet-weight: Dry-weight at the end of incubation.

This procedure was considered preferable to that of weighing before and after incubation and expressing the result as increase in weight, since it eliminates errors due to tissue disintegration and loss.

As the Table (overleaf) shows, the Wet-weight: Dry-weight ratio of the control retinae was 6·4, whereas retinae which were incubated in the presence of iodoacetate or fluoride yielded values of 9·6 and 9·66 respectively, representing an increase of approximately 50 per cent. over the controls. In both cases the difference is statistically significant.

TABLE

MEAN WET-WEIGHT:DRY-WEIGHT RATIOS OF RETINAE AFTER INCUBATION FOR 1 HOUR WITH GLUCOSE SUPPLEMENTED KREBS-RINGER-BICARBONATE

Inhibitor present where stated

Inhibitor	Number of Retinae	Wet-weight:Dry-weight
None	5	6·40 ± 0·34
0·001 M. Iodoacetate	6	9·60 ± 0·50 p = 0·001*
0·01 M. Fluoride	6	9·66 ± 0·66 p = 0·003*

* Indicates that the difference between this result and that of the controls is statistically significant.

Both iodoacetate and fluoride are known to be powerful inhibitors. The *in vitro* fluoride inhibition of glycolysis has been demonstrated in a variety of tissues and the retina has been shown to be particularly sensitive (Dickens and Greville, 1932). Iodoacetate is an effective thiol enzyme poison, combining with the SH groups of proteins, glutathione, cysteine, and coenzyme A. It thus exerts a widespread influence on glucose breakdown. Phosphoglyceraldehyde dehydrogenase is particularly sensitive (Rapkine, 1938). It produces *in vivo* a characteristic rod cell degeneration in the rat, which has been attributed to glycolytic inhibition (Noell, 1952).

The efficiency of these inhibitors was checked during several of the runs by measuring the CO_2 evolution manometrically in the presence or absence of the inhibitor. Changes in tonicity due to the addition of the inhibitor cannot be responsible for the differences observed in the ratios, as the same volume of glass-distilled water was added to the control flasks. It would appear therefore that there is a definite correlation between the inhibitory properties of iodoacetate and fluoride and the swelling of the retina. This supports the concept that constancy of cell size can be maintained only when an adequate source of energy is available. The manner in which these two processes are coupled is still a matter for speculation. It has been suggested that hypothetical energy-driven "pumps" located in the mitochondria may be responsible (Bartley, Davies, and Krebs, 1954).

Mudge (1956) points out that there is still some controversy as regards the postulate that the cell is hypertonic to extracellular fluids during life (Conway and McCormack, 1953). Experimental evidence clearly indicates, however, that swelling does occur when the metabolism is inhibited, even though the nature of this swelling is unknown. It may be isosmotic (Mudge, 1956).

These results may also explain an observation by Terner, Eggleston, and Krebs (1950), in investigating the role of glutamic acid in the transport of

potassium in brain and retina, that retinae incubated in bicarbonate saline under aerobic conditions with glucose and glutamate increased in weight by about 10 to 15 per cent. Retinae incubated anaerobically without a substrate lost about 15 to 30 per cent. of their initial wet-weight. They ascribed the weight loss to tissue disintegration. This fragility, and the opacity they noted, may well have been a result of cellular oedema. Fig. 3 shows the rapidity with which iodoacetate-induced swelling occurs. After 15 minutes the shortest time interval observed, swelling is almost maximal.

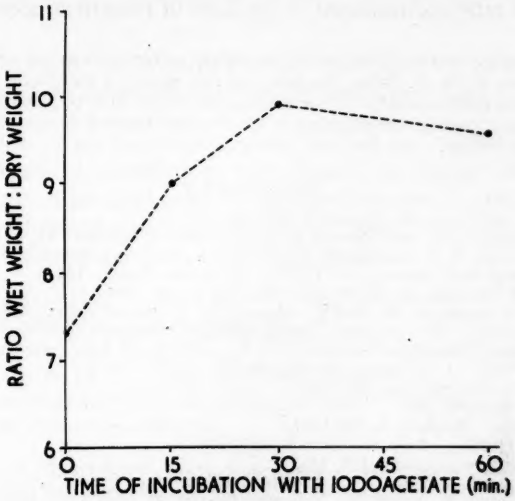

FIG. 3.—Changes in the Wet-weight : Dry-weight ratio during incubation of the retinae with 0·001 M. iodoacetate in Krebs-Ringer-bicarbonate. Each point represents the mean of three determinations.

Conclusions

Although these results clearly indicate a relationship between retinal oedema and inhibition of metabolism by iodoacetate and fluoride, it is too early to assess the importance of this phenomenon as a causative factor of vaso-obliteration. Observations on fluoride-induced vaso-obliteration in the retina of the kitten do provide some evidence for an accompanying retinal oedema, notably the development of a milky-white opacity as the vessels close, and a reversal of vascular closure by injecting hypertonic solutions into the vitreous (Ashton and others, 1957). These workers also point out that intracellular or extracellular oedema can be demonstrated histologically in the inner layers of the kitten retina subjected to oxygen, sodium fluoride, or sodium iodoacetate treatments, but the possibility that these are artefacts is stressed. Further work is yet required to elucidate this complex problem.

Summary

(1) Simple procedures for the removal and weighing of rat retinae are described.

(2) The Wet-weight:Dry-weight ratio has been determined in rat retinae after incubation in Krebs-Ringer-bicarbonate supplemented with glucose.

(3) The ratio was determined in retinae in which the metabolism was inhibited by sodium fluoride or sodium iodoacetate.

(4) The large and statistically significant difference which was observed between these ratios is discussed in the light of present concepts.

I am greatly indebted to Prof. Norman Ashton for his encouragement and advice in this work. My thanks are due to Dr. C. Pedler for designing and preparing the plastic block and holder, to Mr. A. Lakeman for his valuable technical assistance, and to Miss E. FitzGerald for secretarial help. I wish to acknowledge the assistance of the Medical Research Council by a grant towards the expenses of this work.

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Brit. J. Ophthal. (1958) **42**, 355.

COLOUR VISION SURVEY

USING THE ISHIHARA, DVORINE, BOSTRÖM AND KUGELBERG, BOSTRÖM, AND AMERICAN-OPTICAL HARDY-RAND-RITTLER TESTS*

BY

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A COLOUR vision survey has recently been carried out on 500 subjects at the Imperial College as a contribution to a *Report on Colour Vision Tests* prepared by a Committee appointed by the International Council of Ophthalmology. Five different sets of confusion chart tests (commonly referred to as pseudo-isochromatic plates) were used, as follows:

(1) Ishihara (1951)—Japanese, 24 plates with digits.
(2) Dvorine (1953)—American, 14 plates.
(3) Boström and Kugelberg (B-K) (1944)—Swedish, 18 plates.
(4) Boström (B II) (1950)—Swedish, 14 plates.
(5) American-Optical Hardy-Rand-Rittler (A-O HRR) (1955)—American, effectively 4 plates.

Supplementary observations were also made where required with the Nagel anomaloscope and the Farnsworth-Munsell 100-hue test.

The aim of the survey was to evaluate the merits of each test for screening colour normals from colour defectives, with the selection of drivers of public vehicles especially in mind. This paper, however, is confined to a report and discussion of the data recorded at the Imperial College, and gives the views of the authors, and not of the Committee as a whole, on the general evaluation of the tests for screening purposes.

Test Procedure

500 subjects (468 males and 32 females) were selected at random from the staff and students at the Imperial College, and each of them was shown the complete range of plates, which were viewed in daylight at the normal reading distance. In the case of obvious defectives who made many mistakes, the plates were shown once only. For all other subjects, any plate called wrongly at the first showing in the B-K, B II, or A-O HRR test was presented a second time in accordance with the instructions for the test in question. The five sets were shown in random order, so that neither familiarity with the nature of the test nor fatigue prejudiced the

* Received for publication November 19, 1957.

rating of one test relative to another. Not more than 5 seconds were allowed for the reading of a plate in the Ishihara, Dvorine, and A-O HRR tests, and fifteen seconds in the case of the B-K and B II tests, although this amount of time was seldom required. With a normal observer all the plates in the five tests could be shown and answered in about five minutes. Any error made and spontaneously corrected was scored as a correct response.

Analysis of Results

In the initial survey of the 500 subjects, the following passing scores were assumed:

Ishihara —Not more than three errors.

Dvorine —Not more than one error.

B-K, *B II* —No errors on second showing of miscalled plates unless subject was recorded as normal by the other four tests, in which case one error was allowed.

A-O HRR—No errors on second showing of miscalled plates.

If, on these criteria, a subject passed all five tests, he was classified as normal; if he failed all five tests, he was classified as defective; if he passed some tests and failed others, he was left unclassified.

On this basis a first classification was made as follows:

Normal	428
Defective	*36*
Unclassified	36

The 36 unclassified subjects were then re-tested on a subsequent occasion by supplementary tests on the Nagel anomaloscope and, where possible, by the Farnsworth-Munsell 100-hue test. The original uncertainty in the classification of this group had in most cases arisen from mistakes made with the difficult B-K and B II tests, and this second diagnosis showed that 34 of the group were normal and only two were defective, leading to a final division of the 500 subjects into:

Colour normals	462
Colour defectives	38

The number of errors made by these two classes in each of the five tests is shown in Table I (opposite), using the tabulation adopted by Sloan and Habel (1956). A good screening test will divide the normals and defectives into two compact groups with a minimum of overlap of the borderline cases, but Table I shows that the Dvorine and B-K tests in particular possess long tails in the "defectives" column. There is a significant overlap, too, in the A-O HRR test, where the compactness of the groups is really an artefact due to the small number of screening plates employed. (Additional plates are, in fact, included in the A-O HRR test, but they are intended for the grading of subjects with higher degrees of defect, and although they are admirable for this purpose, do not add to the efficiency of the test for screening borderline

subjects.) It should be added that the subjects marked (*a*) and (*b*) in Table I were shown to be clearly deuteranomalous on the Nagel anomaloscope.

TABLE I

DISTRIBUTION OF ERRORS AMONG 462 NORMAL OBSERVERS AND 38 DEFECTIVES AS DERIVED FROM IMPERIAL COLLEGE SURVEY

Number of Plates Mis-read	Test									
	Ishihara		Dvorine		B-K		B II		A-O HRR	
	Normals	Defectives	Normals	Defectives	Normals	Defectives	Normals	Defectives	Normals	Defectives
0	249	0	417	1(*a*)	422	1(*a*)	406	0	455	2(*a*) (*b*)
1	134	0	43	1(*b*)	33	0	41	0	7	2
2	58	0	2	0	5	1(*b*)	7	0	0	4
3	17	0	0	1	2	0	5	1(*a*)	0	8
4	2	0	0	1	0	0	3	0	0	22
5	1	0	0	0	0	1	0	1		
6	1	1(*a*)	0	1	0	0	0	0		
7	0	1(*b*)	0	0	0	0	0	1(*b*)		
8	0	0	0	1	0	0	0	2		
9	0	0	0	0	0	0	0	3		
10	0	1	0	3	0	4	0	4		
11	0	1	0	2	0	4	0	10		
12	0	1	0	3	0	1	0	9		
13	0	2	0	7	0	3	0	6		
14	0	1	0	17	0	10	0	1		
15	0	3			0	13				
16	0	0								
17	0	2								
18	0	3								
19	0	9								
20	0	13								

It is not easy to evaluate the distributions in Table I satisfactorily, but one possibility is to weight each defective who has penetrated into the normal spread by the number of levels to which he has penetrated. Thus, in the Ishihara test, one defective has penetrated by one level only, giving a score of 1; in the Dvorine test, one defective has penetrated by two levels and another by three levels, giving a score of 5; in the B-K test, there is one two-level and one four-level penetration, giving a score of 6; in the B II test, there is one two-level penetration, giving a score of 2; in the A-O HRR test, there are two one-level and two two-level penetrations, giving a score of 6.

On this basis the tests can be rated as follows:

Test	*Weighted Overlap*
Ishihara	1
B II	2
Dvorine	5
B-K	6
A-O HRR	6

It could be argued that, in this method of rating, the small number of plates in the A-O HRR test has worked to its advantage, since this must inevitably limit the penetration. But this rating does at least bring out the superiority of the Ishihara and B II tests in regard to the overlap of the error distributions, which is the most important feature of Table I.

Screening Efficiency of Individual Plates

It is of interest to compare not only the merits of each test taken as a whole, but also the screening efficiencies of the individual plates. With a perfect plate, every normal subject would read the plate correctly while every defective would read it incorrectly. The inefficiency of a plate can therefore be assessed from the number of normals who mis-read it and the number of defectives who read it correctly, and this information is given in Table II for

TABLE
SCREENING EFFICIENCY OF

Test	Plate Number in Each Series	1	2	3	4	5	6	7	8
Ishihara	Number of Normals Mis-reading	—	0	0	38	2	1	13	3
	Number of Defectives Reading Correctly	—	15	19	2	6	0	5	2
	Screening Inefficiency Number	—	15	19	40	8	1	18	5
Dvorine	Number of Normals Mis-reading	—	6	4	8	4	9	0	1
	Number of Defectives Reading Correctly	—	6	5	6	10	6	11	7
	Screening Inefficiency Number	—	12	9	14	14	15	11	8
B-K	Number of Normals Mis-reading	0	0	0	0	0	2	—	—
	Number of Defectives Reading Correctly	8	16	1	10	17	3	—	—
	Screening Inefficiency Number	8	16	1	10	17	5	—	—
B II	Number of Normals Mis-reading	—	0	0	4	21	0	0	20
	Number of Defectives Reading Correctly	—	13	29	3	5	9	7	0
	Screening Inefficiency Number	—	13	29	7	26	9	7	20
A-O HRR	Number of Normals Mis-reading	—	—	—	—	6	1	0	0
	Number of Defectives Reading Correctly	—	—	—	—	2	4	10	14
	Screening Inefficiency Number	—	—	—	—	8	5	10	14

all the plates used in all five tests. The so-called "Screening Inefficiency Number" of each plate is then shown in the Table as the sum of the two mis-classification scores.

Table II confirms that a few of the plates approach very near to the ideal, while a number of others are very inefficient. Hence a judicious selection of plates from each series would evidently produce a highly efficient screening test. Nevertheless, the ability to read these confusion charts is governed by a number of factors, such as the subject's colour-matching functions, spectral sensitivity, colour discrimination, pigmentation, luminance discrimination, temperament, and perhaps also his visual acuity. To design a plate or

plates that will test colour discrimination independently of these other factors is therefore extremely difficult, if not impossible. By a suitable choice of plates, a test can evidently be made so hard that no defectives are passed, or so easy that no normals are rejected. For the occasional borderline subject who cannot be classified by these means, other tests, such as the Nagel anomaloscope, employing light of greater spectral homogeneity, must be used.

Variations in colour printing between one copy of a test and another may also affect the subject's ability to read the plates. Any printer undertaking the production of a confusion chart test is therefore faced with the responsibility of maintaining the colour quality of the plates to within very close limits, and unless he is prepared to accept this the test will have only a limited validity.

II

INDIVIDUAL PLATES IN EACH SERIES

9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
124 0	2 8	2 7	13 1	34 2	0 5	0 6	9 6	63 1	— —	— —	— —	— —	12 5	0 8	3 6	1 6
124	10	9	14	36	5	6	15	64	—	—	—	—	17	8	9	7
7 4	5 4	0 12	1 5	2 6	0 8	0 3	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —
11	9	12	6	8	8	3	—	—	—	—	—	—	—	—	—	—
0 9	4 3	0 4	30 2	0 2	1 5	— —	10 3	1 2	1 8	— —	— —	— —	— —	— —	— —	— —
9	7	4	32	2	6	—	13	3	9	—	—	—	—	—	—	—
3 1	1 1	5 16	24 4	4 1	0 3	0 32	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —
4	2	21	28	5	3	32	—	—	—	—	—	—	—	—	—	—
— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —
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INCIDENCE AND TREATMENT OF TRACHOMA IN PAKISTAN*

BY

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TRACHOMA is the cause of great human suffering in Pakistan, but no firm data of its incidence are available. Recently D.D.T. sprays and other anti-fly measures have assisted the prophylaxis of trachoma but have by no means lessened the importance of its treatment. The incidence of trachoma in Pakistan and the relative merits of various forms of therapy are discussed below.

Geographical Situation of Pakistan

The country consists of two wings—East Pakistan and West Pakistan—separated from each other by 1,500 miles of land. By far the greater part of the population (Table I) is concentrated in the relatively small area of East Pakistan in the delta formed by the Ganges and Brahmaputra rivers, which is the most densely populated part in the world and is conspicuous for its high rainfall (77 inches). The climate is humid, winters and summers are mild, and there are no sandstorms. In West Pakistan, which is divided into four provinces, mountain ranges run down the western borders, extending from the Himalayas to the sea, and the basin of the river Indus stretches out in wide plains from the foot of the mountains in the north. The mountainous area includes the North-West Frontier province and Baluchistan, and comprises much desolate, waterless, and sparsely populated country. In the plains lie the Punjab—the land of five rivers, a fertile agricultural area, and Sind, through which run the lower reaches of the Indus,

TABLE I

DISTRIBUTION OF POPULATION (CENSUS, 1951)

Wing	Population (millions)		Sex Distribution (millions)				Area (thousands of sq. miles)	Population (per sq. mile)
			Male		Female			
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.		
East Pakistan ..	42	55	22	29	20	26	54	777
West Pakistan..	34	45	18	24	16	21	312	135
Total ..	76	100	40	53	36	47	366	208

* Received for publication March 12, 1957.

where irrigation is steadily spreading its benefit into the once barren soil; this last province has little rainfall (7 inches), the climate is extreme both in winter and summer, and the atmosphere is dusty with frequent summer sandstorms (Fig. 1).

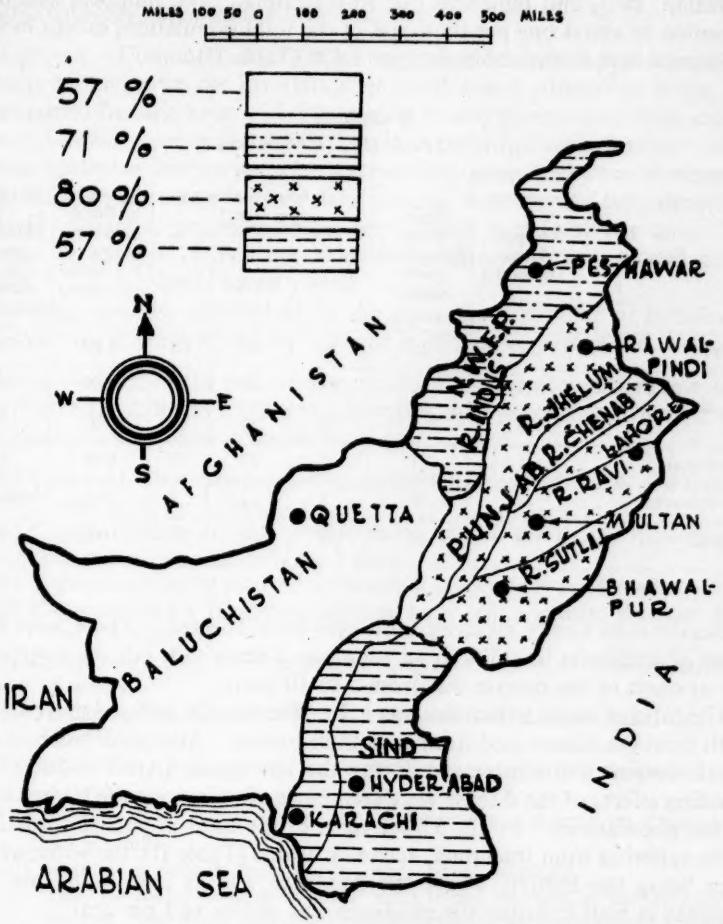

FIG. 1.—Map of the four provinces of West Pakistan.

Incidence of Trachoma†

Sample Examined.—It has not yet been possible to make a country-wide survey of trachoma, but the following method has been adopted where surveys have been made, and in this way a sample has been taken of the whole population.

† Figures for East Pakistan were provided by Prof. M. Refatullah, Medical College, Dacca.

The hospital out-patients who attended the ophthalmological clinics from 1949 to 1955 were grouped by age, sex, and place of residence. They were examined for evidence of trachoma, active or quiescent, the complications of trachoma (such as ptosis, trichiasis, entropion, xerosis, corneal opacities, ulceration, etc.), and blindness due to trachoma. The numbers examined amounted to about one per thousand of the total population, except in East Pakistan, where it was about one per 1,400 (Table II).

TABLE II
INCIDENCE OF TRACHOMA

Area	Population (millions)	Population Examined (thousands)	Trachoma Incidence (per cent.)			Incidence of Blindness due to Trachoma (per cent.)	Incidence of Trachoma with Complications (per cent.)
			Active	Healed	Total		
Punjab	21	21	51	29	80	0·10	31
North-West Frontier	5·9	6	43	28	71	0·09	26
Sind	6	6	35	22	57	0·07	21
Baluchistan	1·1	1	30	27	57	0·06	18
East Pakistan ..	42	30	1	1	2	Nil	Negligible
Total	76	64	32	21	53	0·08	24

Results.—In nearly all cases both eyes were affected. There were many cases of trachoma in children as young as 2 years old, but the commonest age at onset of the disease was from 5 to 10 years.

The ratio of males to females was 1:2. The females suffered more severely both from the disease and from its complications. Attacks of trachomatous kerato-conjunctivitis increased during the hot season (April to July). The blinding effects of the disease were seen more often among the poorer classes of the populations. In all, 53 per cent. of the total population was found to be suffering from trachoma, active or healed (Table II), the worst-affected area being the Punjab, where the incidence was as high as 80 per cent., whereas in East Pakistan the incidence was as low as 2 per cent.

It is estimated that 0·13 per cent. of the population of Pakistan (100,000 individuals) are blind from all causes. Trachoma accounted for 0·08 per cent. (Table II), the remaining 0·05 per cent. being mainly due to uveitis, glaucoma, cataract, senile macular degeneration, and optic atrophy. Trachomatous complications, such as ptosis, trichiasis, entropion, xerosis, corneal opacities, and ulcerations, were seen in 24 per cent. of those examined.

Treatment

Selection of Cases for Treatment.—Cases of Stage II trachoma (MacCallan, 1908) of the infiltrative or follicular type, showing corneal infiltration and pannus on slit-lamp microscopy and having similar clinical features and symptomatology, were selected for treatment.

Diagnosis.—Conjunctival scrapings were taken from the upper fornix with a sharp curette, after the instillation of cocaine and adrenaline drops, and were stained for one hour with 10 drops of freshly prepared Giemsa stain to 10 ml. distilled water to establish the presence of inclusion bodies. Intracellular inclusion bodies are characteristically seen in the early stages of trachoma, and therefore, because those selected were cases of fully-developed Stage II trachoma, inclusion bodies were found in only 12 per cent. The presence or absence of inclusion bodies was ignored in assessing diagnosis or cure.

The diagnosis was established by the presence of papillae or follicles (*in vivo*) evidence of infiltration, and pannus in the upper part of the cornea.

Therapy.—Each of the following methods of treatment was tried in twenty cases (Table III, overleaf). Ten further cases, used as controls to each group, were given normal saline drops only.

(*i*) 1 per cent. silver nitrate solution applied to the everted eyelids and fornices once daily for 7 days.
(*ii*) Copper sulphate crystals touched to the everted eyelids and fornices after cocainization once daily for 7 days.
(*iii*) Sulphacetamide 30 per cent. ointment six times daily for 6 weeks.
(*iv*) Chloramphenicol (Chloromycetin) as 1 per cent. ointment six times daily for 6 weeks.
(*v*) Chlortetracycline (Aureomycin) as 1 per cent. ointment six times daily for 6 weeks.
(*vi*) Oxytetracycline (Terramycin) as 1 per cent. ointment six times daily for 6 weeks.
(*vii*) Tetracycline (Achromycin) as 1 per cent. ointment six times daily for 6 weeks.
(*viii*) Curettage weekly and 1 per cent. Achromycin ointment six times daily for 6 weeks.
(*ix*) Combined curettage, Achromycin, and copper sulphate.
This was the same as (*viii*) above for 5 weeks followed by copper sulphate touched once a day and Achromycin ointment six times daily for the one remaining week.

Criteria of Cure.—Disappearance of symptoms; clearance of pannus and follicles; cicatrization of lid lesions; no relapse up to 6 months. A case was said to be cured only when this standard of recovery was achieved.

Results.—Silver nitrate for short periods was found to have little effect on trachoma, apart from clearing the secondary infection. Longer treatment

TABLE III
EFFECTS OF DRUGS ON THE TREATMENT OF TRACHOMA

Treatment	No. of Cases Treated	Results							
		Clearance of Secondary Infection within 48 hrs		Clearance of Pannus at End of Treatment		Relapse (up to 6 mths)		Cured (no relapse up to 6 mths)	
		No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Silver Nitrate	20	4	20	Nil	Nil	20	100	Nil	Nil
Copper Sulphate	20	11	55	4	20	17	85	3	15
Sulphacetamide 30 per cent.	20	18	90	12	60	16	80	4	20
Chloramphenicol	20	16	80	6	30	16	80	4	20
Aureomycin	20	17	85	7	35	15	75	5	25
Terramycin	20	16	80	5	25	17	85	3	15
Achromycin	20	19	95	9	45	14	70	6	30
Curettage and Achromycin	20	18	90	11	55	12	60	8	40
Curettage, Achromycin, and Copper Sulphate ..	20	17	85	16	80	9	45	11	55
Curettage, Achromycin, and Sulphacetamide 30 per cent.	20	18	90	13	65	11	55	9	45

was not tried for fear of argyrosis. During treatment there was apparent improvement clinically, but all cases relapsed within a short period of discontinuance of treatment.

Copper sulphate, the established "sheet-anchor" treatment of trachoma, was found to be of some value.

Of the antibiotics, Achromycin gave better results than the others, accounting for 30 per cent. of cures.

Combined treatment with curettage, Achromycin, and copper sulphate was the most efficacious, accounting for 55 per cent. of cures.

The controls to groups (*i*) and (*ii*) were treated for 7 days with normal saline, and the controls to group (*iii*) to (*ix*) were treated for 6 weeks. In general, not much improvement was noticed in the control cases; some improvement occurred spontaneously in a few cases, but the majority became worse during the 6-week period of observation, and specific treatment had to be started because of the deterioration of their clinical condition.

The systemic administration of antibiotics was found to have no advantage over topical application. Ointment was found to be better than drops,

probably because it stays longer in the conjunctival sac and is not readily washed away by tears.

Discussion

Incidence.—A comparison of population densities in East and West Pakistan may appear misleading (Table I), because it may be thought that the population may be as dense in the cultivable areas of West Pakistan as it is in East Pakistan, but this is not so. In East Pakistan 55 per cent. of the total population occupies one-seventh of the total area of the whole country, and in West Pakistan the remaining 45 per cent. of the total population occupies about three-sevenths of the total area, the remaining three-sevenths being uninhabited and unproductive mountains and deserts (Slade, 1955). According to the Census of 1951, all the sixteen districts of East Pakistan have a population of over 500 persons per square mile (the actual average being 777), while only seven of the 46 districts of West Pakistan have a population of over 500 persons per square mile (the average being 135). The average populations of the four provinces of West Pakistan are shown in Fig. 2.

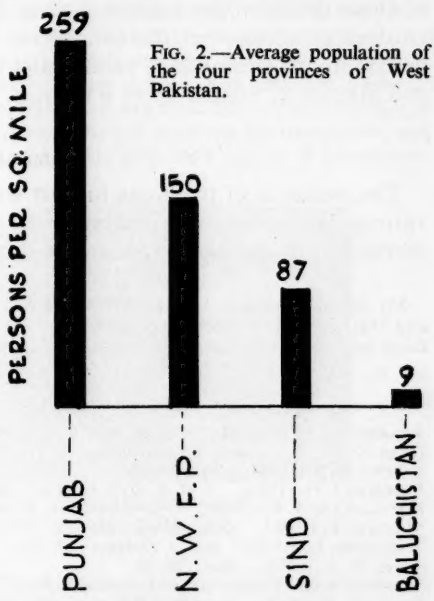

FIG. 2.—Average population of the four provinces of West Pakistan.

It is at first sight surprising that, in spite of this heavy overpopulation, the incidence of trachoma in East Pakistan is so low (1 to 2 per cent.), but this is probably caused by the following factors:

(*a*) *Personal Hygiene.*—East Pakistanis are particular about personal cleanliness; morning and evening baths are taken routinely even by lower classes of the population.

(*b*) *Comparative Freedom from Insect Vectors.*—Flies, ticks, and bugs are fewer than in West Pakistan.

(*c*) *Heavy Rainfall.*—East Pakistan is called the land of rivers and green vegetation, and the abundant rain (77 inches annually) cleanses the filth, dirt, and squalor.

(*d*) *High Humidity.*—The humid climate with mild summers and winters appears to lower the endemicity of the disease; contiguous countries, like Burma, Siam, and Malaya, which have a climate similar to that of East Pakistan, also have a low incidence of trachoma.

(*e*) *Rarity of Sandstorms.*—The atmosphere is comparatively free from dust.

In West Pakistan, on the other hand, 66 per cent. of the population were found to have active or healed stigmata of the disease, the Punjab being the most heavily affected area (80 per cent.), followed by the North-West Frontier, Sind, and Baluchistan, in that order (Table II). The dust, heat, drought, sandstorms, meagre rainfall, and extremes of climate, which may be called "ripening factors" for trachoma, all help to bring this about, and the higher incidence in the Punjab and North-West Frontier provinces may be ascribed to the denser population and to the fine, irritant sand particles which arise from the nature of the soil in these areas.

The incidence of trachoma in East Pakistan may rise because of the gradual increase in the interchange of population between East and West Pakistan.

Treatment.—Encouraging reports of the results of using sulphonamides and antiobiotics have appeared (Lavery, 1946; Duke-Elder, Ainslie, and Boase, 1950; Magnol, 1950; Naccache, 1953; Agarwal and Malik, 1955), but others found some of them of little value apart from clearing the secondary infection (Leopold, 1951; Shah, 1951; Siniscal, 1952).

In the series reported above, it has not been possible to assess the efficacy of these drugs on the trachoma virus because of the lack of facilities for virological studies, but the clinical results, as judged by the disappearance of symptoms, clearance of pannus and follicles, cicatrization of lid lesions, and absence of relapse up to 6 months, are encouraging.

Summary

The incidence of trachoma in East and West Pakistan and the efficacy of various antibiotics in its treatment are analysed. Achromycin 1 per cent. ointment with curettage and copper sulphate gave the best results.

My thanks are due to Lt.-Gen. W. A. Burki, C.B.E., Director General of Medical Services, and Maj.-Gen. M. N. Mahmood, Director of Medical Services, for their permission to publish these findings, and to Prof. M. Refatullah for supplying statistics for East Pakistan.

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CASE NOTES

ENDOTHELIOMA OF THE OPTIC NERVE*

BY

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Case Report

An unmarried woman, aged 36, came to the out-patients' department with a history of having lost the sight of her left eye 3 years ago. The condition was diagnosed in another hospital as thrombosis of the central vein, and she was kept under 3-monthly observation. As far as she knew no aetiology of the trouble was ever found, and my direct inquiries at the source confirmed this.

Examination.—She was a fit woman at the time of her visit, with a blind left eye (no perception of light), and a typical enlarged amaurotic pupil. The right eye was normal. The left fundus showed a chalky white papilla with ? glial overgrowth at its lower half. The retinal vessels were seen to arch with this glial tissue and to dip to the fundus level at its border. All vessels—arteries as well as veins—were very thin, and the retina was pale. There were no haemorrhages or exudates. This eye showed some limitation of upward and inward movement and it seemed to me proptosed, but these last two features were so indefinite that I asked the patient to bring me some old snapshots for comparison and, there was not much to go by even then (Fig. 1). She also had a history of tuberculosis.

FIG. 1.—Left proptosis exaggerated by utilizing the position of the eyes in which the patient's slight exophoria is best seen.

Diagnosis.—Tumour of the optic nerve, probably a glioma. From the clinical history it was deduced that the tumour started within the distal 10–15 mm. of the nerve, as occlusion of the central vein was the first sign of trouble.

Operation.—The proptosis was very indefinite and the x ray of the optic canal was normal I delayed surgery, but after 3 months of observation she was admitted to hospital for

* Received for publication May 16, 1957.

enucleation. This was started by lateral canthotomy and about 20 mm. of the optic nerve was removed with the globe (Fig. 2). Because of the very anterior location of the tumour I hoped to remove it in this way, without further mutilating surgery, but the section of the distal end of the nerve showed neoplastic infiltration.

FIG. 2.—*Enucleated globe, showing* thickened optic nerve, primary swelling *just behind* the eyeball, and second swelling distally.

The patient was referred to the neurosurgical unit at the Midland Centre for Neurosurgery for transfrontal approach, and a second operation was performed by Mr. R. C. Connolly. The optic nerve at the orbital extremity of the optic canal was found to be normal, and was divided at that point. The tumour, which involved the nerve immediately distal to that point and was densely adherent to the surrounding tissues of the orbit, was eventually removed *in toto*.

Microscopic examination of both specimens proved the *tumour to be an* endothelioma (Fig. 3 and Fig. 4, opposite).

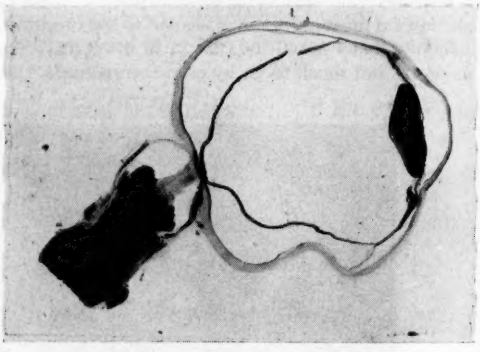

FIG. 3.—Section through globe. ×2.

Comment

This tumour, endothelioma of the optic nerve, is not common. Duke-Elder (1940) traced 33 described cases up to 1933, and all subsequently recorded cases would still not double that figure. In putting this case on record, two problems seem to be worth emphasizing: the diagnosis, and the nature of the proptosis.

The clinical diagnosis in this case presented no difficulties, but the pathological diagnosis depended entirely on the pathologist and the microscope. This tumour had all the clinical differential characteristics of a glioma: the comparative youth of the patient, the good mobility of the eye, early

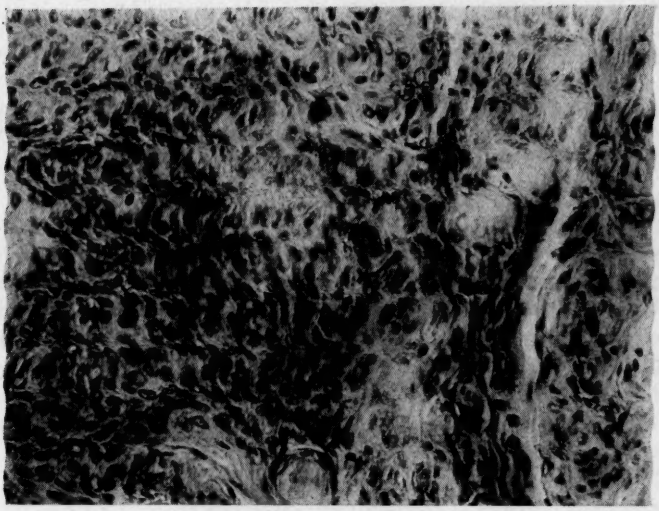

FIG. 4.—High-power magnification of section of tumour, showing typical structure endothelioma.

loss of vision with vascular occlusion, no cranial extension, and no pain, but proved histologically to be an endothelioma. A similar case was described by Stallard (1935) with close retrobulbar localization of the tumour.

Considering only the increase in the bulk of the optic nerve, it seems highly improbable that proptosis is caused in these cases simply by the space-taking of the tumour within a rigid orbit. When I operated I felt that the proptosis was caused by the thickened and unyielding stalk of the optic nerve pushing the globe forward. Because of this thickening the nerve had lost its physiological curves, thus elongating and acting like a stiff rod. Otherwise the tissues of the orbit were lax and freely admitted a finger to palpate the tumour without any further forward displacement of the globe.

It is now about 2 years since the operation was done and the patient has remained well.

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BILATERAL CONGENITAL BUPHTHALMOS IN TWO SISTERS*

BY

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THE relative rarity of familial cases of buphthalmos warrants the following record of two sisters suffering from severe bilateral buphthalmos at present under treatment at the Royal Eye Hospital (see Figure).

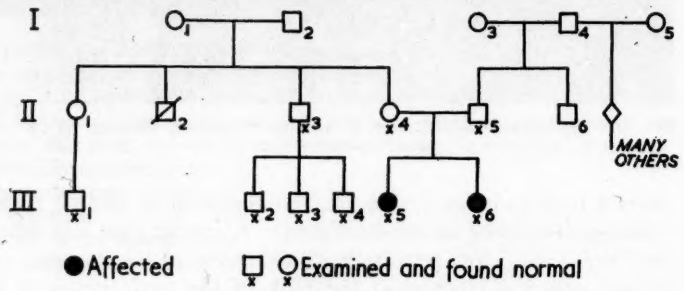

FIGURE.—Pedigree of affected sisters.

Case 1, a girl aged 3 years (III, 5), was born at full term on November 8, 1953.

At birth the corneae were noticed to be enlarged and cloudy, and she was transferred to the Royal Eye Hospital a few days later. On admission both corneae were enlarged and hazy. The anterior chamber was deep in each eye. Fundus details were not seen.

The corneal diameter was 11·5 mm. in the right eye and 12 mm. in the left. The ocular tension was 29 mm. Hg (Schiötz) in the right eye and 28 mm. Hg. in the left. The ocular tension was controlled in the right eye by goniotomy, using Barkan's method; this was repeated five times. The left eye required seven goniotomies and finally a trephine. Since May, 1955, when the child was 18 months old, the tension has remained controlled in both eyes, the corneae are clear, and no drops are required. The optic discs are pale and cupped.

Visual acuity, with illiterate "E" test, Right eye, with −7·5 D sph., 3/24.
Left eye, with −10·5 D sph., 3/60.

Binocular vision, with glasses, 3/18.

Case 2, a female infant aged 5 months (III, 6), was born at full term on February 24, 1957. When she was 5 days old it was noticed that both corneae were cloudy and she was referred to the Royal Eye Hospital. On admission both corneae showed dense annular opacities which made it difficult to estimate the depth of the anterior chambers and prevented ophthalmoscopy. The corneal diameter was 11 mm. in both eyes. The

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ocular tension was 60 mm. Hg. (Schiötz) in the right eye and 45 mm. Hg in the left. A right trephine was performed on April 4, 1957, and a left trephine on May 2, 1957. Both procedures were uneventful. The anterior chambers seemed deep though it was difficult to estimate the position of the limbus. At operation, the corneae were found to have an unusual consistency, the central portions especially feeling hard and fibrous. Despite the presence of satisfactory trephine blebs the ocular tension remains raised.

Discussion

Most cases of buphthalmos are "sporadic", but the available evidence makes it likely that the condition is not infrequently genetically determined. In a successive series of 172 cases, Brons (1937) found nineteen familial examples, and Westerlund (1947) observed 31 familial cases in a series of 122. In the absence of any history of buphthalmos in the antecedents and with the lack of unusual sex distribution amongst the affected, autosomal recessive inheritance is a likely assumption—and this is supported by the high rate of parental consanguinity in both sporadic cases and affected sibs (Sorsby, 1951). In contrast there are several pedigrees suggestive of dominant inheritance. In the present sibship there is nothing to suggest dominant inheritance and, though parental consanguinity is lacking, the history is not inconsistent with recessive inheritance.

Summary

The occurrence of congenital buphthalmos in two sisters is recorded.
The mode of inheritance of buphthalmos is discussed.

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LAURENCE–MOON–BIEDL SYNDROME*

BY

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THE syndrome, consisting of obesity, hypogenitalism, polydactyly, mental retardation, and retinal changes of the retinitis pigmentosa type, is recognized as a clinical entity. It is, however, unusual to find all the manifestations of the syndrome in a single case. The case described here is interesting in that it presented as a complete syndrome.

Case Report

A boy aged 10 years was brought to the children's out-patient department of the Patna Medical College Hospital on account of his abnormal flabbiness and mental deficiency. In addition he had not been able to see very well for some time, particularly at night.

He was the third child of his parents, who were healthy and not consanguineous. The family, traced to four generations on the father's side and three on the mother's, was essentially normal with no history of consanguinity. Two children, a brother and sister, had died in infancy, and as far as could be ascertained showed no ocular or general manifestations of the syndrome. The patient's surviving sister was 12 years old and normal in all respects. His younger brother was aged 4 years, was quite intelligent, but had supernumerary fingers—seven on the right hand, and six toes on both feet. His ocular and general examinations revealed no other abnormality.

Examination.—The patient was obese, and of short stature (height 3 ft 4 in.), and weighed 8 stone. He was dull and listless, and had not started speaking until the age of 5 years.

There was a marked accumulation of fat in the abdominal wall, thighs, hips, and shoulders. Breast and abdomen were pendulous. The genitalia were under-developed with testis descended in scrotum. A supernumerary finger was attached to the little finger of each hand and the right little toe.

Ophthalmic Examination.—There was a fine horizontal nystagmus more marked in darkness. The visual acuity in both eyes was reduced to counting fingers at one metre only. The patient walked unaided in the day, but found great difficulty at night or in darkness and often had to be guided.

The extra-ocular muscles were normal and the pupils were normal in size and reactions. The ocular media were clear.

Fundus Oculi.—Both discs were pale and waxy-looking with a normal physiological cup. The retinal arteries showed marked attenuation, many appearing as mere threads. Pigment was irregularly distributed all over the fundus with no preference for the equatorial or macular areas. The pigment deposits were varied in size and shape and arranged

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in small patches, showing no similarity to the so-called "bone-corpuscle" arrangement typically seen in cases of retinitis pigmentosa. The central nervous system and hearing were normal.

Laboratory Investigations.—Routine blood examinations, including erythrocyte sedimentation rate and blood sugar within normal limits. Wassermann reaction negative.

Glucose tolerance test normal. No sugar in urine.

X rays showed no evidence of any abnormality or decalcification.

Electrocardiogram: sinus arrhythmia.

Discussion

Höring (1864, 1865) and Stör (1865) described cases of retinitis pigmentosa associated with polydactyly, but did not call attention to the possible existence of a new syndrome. Laurence and Moon (1866), considering four cases of retinitis pigmentosa associated with other unusual anomalies, including obesity, hypogenitalism, and mental deficiency, first described this new clinical entity. Their four cases all belonged to the same family of ten children, of whom two died in infancy, four were healthy, and the remaining four were afflicted with visual and general bodily disturbances.

Bardet (1920) further correlated these cases of adiposo-genitalism and retinitis pigmentosa with polydactyly, but did not mention mental deficiency and the familial incidence of the syndrome. These components were added by Biedl (1922), who described two cases in one family.

Burn (1950), in describing two families presenting this syndrome, reviewed the literature exhaustively and tried to ascertain how far deafness could be fitted into the syndrome. He found that of a total of 611 members of affected sibships (in 178 family groups), eighteen were deaf, giving an incidence of 2·94 per cent. (sixty times greater than the percentage of deaf in the general population). These figures strongly suggest that deaf-mutism does not occur merely by chance in the Laurence–Moon–Biedl syndrome but is in some way related to it.

Very many concomitant anomalies associated with this syndrome have since been described both by pediatricians and ophthalmologists. These include:

(*a*) *Eye.*—Nystagmus, microphthalmos, myopia, strabismus, and posterior polar cataract.

(*b*) *General.*—Congenital heart disease, bilateral genu valgum, bilateral hydronephrosis, hypospadias, hypothyroidism, diabetes insipidus, decreased carbohydrate tolerance, tetany, dwarfism, external ophthalmoplegia, and bilateral ptosis (Sussman, 1951).

The Laurence–Moon–Biedl syndrome is not very common. According to Radner (1940), only 200 cases had been reported up to that date. A review of the literature from 1940 to the present day has yielded about eighty more cases (Gantayan and Suryaprasadarao, 1952; Agarwal, 1953; Bergman and Eden, 1954; Wolff and Etzine, 1955). Thus, 280 cases have been reported, in only a fraction of these has the complete syndrome been described, and

of the 102 patients on whom data were tabulated by Warkany, Frauenberger, and Mitchell (1937), only 24 exhibited the complete syndrome.

The onset of the condition occurs in early life and may be detected even before the child reaches school age. The family history is generally negative although some workers have reported alcoholism and mental instability in the family. Consanguinity has varied from 14 per cent. (first cousins) to 23 per cent. (first and second cousins).

The night blindness and the progressive limitation of the visual fields are well-known characteristic symptoms. Although the fundus typically shows a marked attenuation of the vessels, with pigmentary changes of the "bone-corpuscle" type, Cockayne, Krestin, and Sorsby (1935), Sorsby (1941), Ellis and Law (1941), and Taylor (1947) have reported that the range of fundus appearances extends to at least four types: typical retinitis pigmentosa; atypical retinitis pigmentosa with increased pigmentary disturbance in the central area of fundus rather than the periphery; macular dystrophy; atypical retinitis pigmentosa combined with macular dystrophy.

Polydactyly is a hereditary mesoblastic fault or maldevelopment, but the remaining components are ectoblastic in origin and possibly of an abiotrophic nature. The seat of the neuro-ectodermal disturbance is thought to be in the forebrain (prosencephalon) from which develops the optic vesicle to form the nervous and pigmentary layers of the retina.

Bauer (1927) thought polydactyly was dominant and pointed out that it sometimes skipped a generation and was independent of the retinal and cerebral changes which were recessive. Sorsby, Avery, and Cockayne (1939), however, disagreed with this view and put forward two main theories to explain the syndrome:

(1) That one gene produced all the signs and the incompleteness of the syndrome was due to the action of modifying genes, secondary mechanical effects, endocrine disturbances, etc. (Franceschetti, 1930; Franceschetti and Streiff, 1936; Stroesco, 1936; van Bogaert, 1938).
(2) That the syndrome was determined by two or more genes (Bauer, 1927; Rieger and Trauner, 1929; Savin, 1935; Cockayne and others, 1935; Sorsby and others, 1939).

Reiger and Trauner (1929) thought that the mesoblastic and epiblastic parts of the syndrome were recessive and due to mutations of two genes in the same chromosome, one causing the abnormalities of the ectoderm and the other of the mesoderm. According to Sorsby and others (1939), this combination of ectodermal and mesodermal defects makes it more likely that two recessive genes in the same chromosome determine the syndrome, or that it is dependent on some chromosomal error such as dislocation or translocation. Macklin (1936) suggested that there were two genes, one dominant and autosomal and the other recessive and sex-linked. She thought that two recessive genes in an autosome could not account for the high ratio of affected to normal children or for the great excess of the males.

Summary

A classical case satisfying the five cardinal diagnostic criteria of the Laurence–Moon–Biedl syndrome, as suggested by Warkany and others (1937), is described. An additional interesting fact is that the younger brother of the case was otherwise normal except for polydactyly.

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Brit. J. Ophthal. (1958) **42**, 376.

APPLIANCES

NEW DESIGN IN ANTERIOR CHAMBER LENSES*

BY

T. G. WYNNE PARRY

Bangor, North Wales

MORE and more attention is being paid to the question of intra-ocular acrylic implants since Ridley's original venture into this field.

More recently, interest has changed from Ridley's original idea of an acrylic lens replacing the extracted lens in position behind the pupil to the anterior chamber implant.

It is possible that this has happened because of the greater ease of insertion of the anterior chamber lenticulus and the fact that it is easier to take such a lens out should anything go wrong; furthermore, the anterior chamber lens has the great advantage over Ridley's lens of being capable of insertion after an intra-capsular operation or a cataract extraction with full iridectomy or both.

The best known of the anterior chamber lenses in use at present is the Strampelli lens, which is made entirely in plastic; the shape being approximately as shown in Fig. 1.

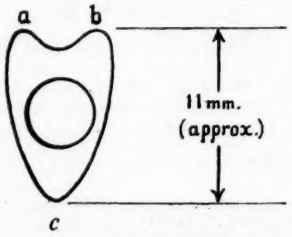


FIG. 1.—Shape of lens.

It is inserted into the anterior chamber through a small incision and is held in position by each of the three projecting points (a, b, c) being jammed into the drainage angle between the root of the iris and the cornea. There are other modifications of this lens, some with three legs and some with spring loops of various materials, but essentially the mode of fixation is the same, by means of pressure against the iris root and cornea in the region of the filtration angle.

Owing to the exact fit required in this type of lens, it is necessary to make two or three lenses for each case and, by trial and error, to select the one that fits not too loosely and not too tightly, with just the right pressure in the angle.

* Received for publication July 15, 1957.

I have felt for the last year or more that a lens which relies for its fixation on pressure in such a delicate part of the eye as the root of the iris cannot be entirely free from the danger of causing iris atrophy and possibly other troubles.

The new type of lens described below has therefore been designed with the following objects:

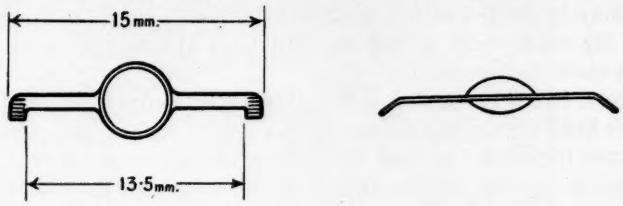
(1) To avoid the dangers of pressure in the filtration angle.

(2) To be easy to insert and, if necessary, to extract.

(3) To be capable of implantation at the time of the extraction of the cataract if desired; this is hardly possible with the Strampelli lens.

(4) To avoid the necessity for making a series of lenses of different sizes for each case to ensure a good fit.

Construction.—The lens (Fig. 2, *a* and *b*), made of Transpex I (I.C.I.), is held in a small tantalum frame with two projecting arms; the end of each arm has a small downward projection, similar to a letter "L" lying on its side; these are also bent backwards at an angle of approximately 145°.



(*a*) (*b*)

FIG. 2.—Lens in tantalum frame. (*a*) Front view. (*b*) Side view with front upwards.

The width of the frame from the end of one arm to the end of the other is 15·5 mm., and the distance between the downward projections is 13 mm. The vertical width of the arms is 1·5 mm. A line drawn along the lower edges of the arms passes through the centre of the lens.

Technique of Insertion.—A small conjunctival flap is raised on both sides of the cornea and dissected well on to the cornea, as for a trephine operation. At the side, where it is intended to insert the lens into the anterior chamber, a corneo-scleral mattress suture is placed. Originally, a Beers's knife was used for the section of the cornea; the knife was passed through the corneo-sclera as close to the iris as possible without touching it, and the point emerged on the opposite side of the anterior chamber at a corresponding position, being passed through far enough to make the wound on the opposite side large enough to allow the passage of one of the tantalum arms of the frame.

The level of the lower part of the section of the Beers's knife passed in front of the centre of the pupil, so that the centre of the acrylic lens was on the same plane.

A Beers's knife was used so that there could be a large enough incision on the "inserting side" for the lens itself to pass through, whereas only a small incision was necessary on the other side for the leading tantalum arm to pass into.

The arm of the lens is seized at the tip with a pair of forceps made for the purpose and, with the large incision held open, the lens is passed across the anterior chamber and the end of the leading tantalum arm is engaged in the incision on the opposite side. The lens is then moved downwards until the lower edges of the arms rest at the bottom of the two incisions and the lens is centred in front of the pupil. The small downward projections at the end of each arm prevent the lens sliding out to one side or the other.

The corneo-scleral mattress suture is drawn tight and the bent ends of the arms are adjusted to the curve of the sclera if the angle at which they are bent is too great. This is done by slipping the point of a von Graefe or other knife under the little projecting tips and gently pressing the angle out with any small blunt instrument.

The conjunctival flaps are now sutured back into place and the anterior chamber may be refilled with a penicillin solution. Atropine can be safely used and the usual toilet of the eye performed afterwards. Figs 3 and 4 (opposite) show the lens *in situ*.

It has been found better in a recent case to use a straight-backed Smith's von Graefe knife for the first section, as this gives a cleaner flatter wound, and it also makes it possible to keep the incisions strictly parallel to the face of the iris; this is important as the two flat tantalum arms will be sealed in this position later.

After the incision with the von Graefe knife, the wound on the side at which it is proposed to introduce the lens can be enlarged with corneo-scleral scissors.

Healing.—For some years I used tantalum drains, which were made in the form of a channel and were inserted under the conjunctiva through the corneo-sclera into the anterior chamber. In spite of their shape, which should have facilitated drainage, the wound effectively sealed up these drains after some months. I do not, therefore, anticipate that there will be the least leakage of aqueous through the wounds in which the thin and flat tantalum arms are sealed in place.

Tolerance.—It is now recognized that tantalum is tolerated extremely well in the anterior chamber, and I have noticed no change in tantalum drains which have been left in the eye over several years. The tolerance of the eye to the material of the lens has, of course, had a fairly extensive trial with both the Ridley and Strampelli lenses. There should, therefore, be no fear of reaction to either of these materials in the eye.

Refraction.—If the lens is inserted at the time of the extraction, then a lens equivalent to approximately +10 D can be put in, but, if it is desired

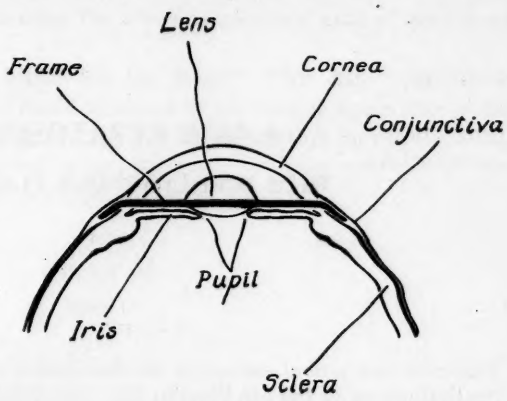


FIG. 3.—Diagram of lens *in situ*.

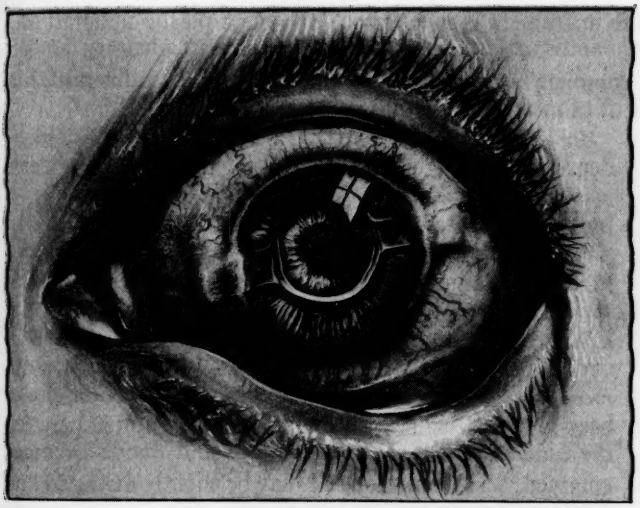


FIG. 4.—Drawing of eye with lens *in situ*.

to put the lens in at a later date, the lens can be ground to the patient's refraction.

Asepsis.—I have found it satisfactory first to clean the lens gently with a soft camel hair brush with warm soap and water and then to rinse it thoroughly with sterile water, place it in a solution of cetrimide for 10 to 15 minutes, rinse it again with sterile water, and finally place it in a concentrated solution of penicillin for half an hour or more.

The lenses are manufactured by Messrs. G. Nissel & Company, Siddons Lane, Baker Street, London, N.W., and the special forceps by Messrs. Dixey, 19, Wigmore Street, London, W.1. I owe my thanks to both firms for the time and trouble they have taken.

Brit. J. Ophthal. (1958) **42**, 380.

A NEW KERATOSCOPE*†

WITH SELF-LUMINOUS PLACIDO DISC

BY

M. KLEIN

London

THIS new instrument embodies the features of the Placido disc, but obviates the limitations of the old Placido disc, which has been found rather cumbersome for routine use.

The head of the instrument is made of a very tough plastic material and the concentric light and dark circles are illuminated through a battery handle, thus making the complete keratoscope convenient to handle, readily portable, and independent of external illumination (Figure).

In all surface irregularities of the cornea, elevations or depressions, irregular astigmatism, alignment of corneal grafts, etc., the distortion of the circular pattern is immediately discernible.

In the early stages of keratoconus, the horizontal and vertical crosslines are especially useful where the circles may still be regular but the two halves of the horizontal axis form an angle, which is the earliest sign of conical cornea (Amsler). In the later stages this angle becomes more marked, the distance between inner and outer circles becoming smaller temporally and below, while that between the inner and outer circles nasally and above becomes enlarged. The central circle may be slightly distorted and displaced downwards and outwards.

A further diagnostic procedure in cases of conical cornea is to ask the patient to look at the centre, then along the horizontal line at the innermost circle, first to the left and then to the right, then up and down along the vertical lines. This enables the central portions of the cornea to be explored. In the early stages of keratoconus it is found that an oscillation or rocking of the mires becomes apparent when the patient looks at these different points. The usual photograph taken by the keratograph gives a picture of the centre only, whereas with

* Received for publication May 13, 1957.

† Manufactured by Messrs. Keeler, London, W.1.

the keratoscope one can examine the whole paracentral area of the cornea in a few seconds.

The keratoscope head, which fits the Keeler 'New Era' ophthalmoscope handle, will be found a useful addition to the routine equipment of the ophthalmologist. The performance of this keratoscope is an improvement on the old placido disc as marked as that of the self-luminous ophthalmoscope in comparison with the reflecting type of instrument.

Brit. J. Ophthal. (1958) **42**, 382.

BOOK REVIEWS

Contact Lenses. By T. E. OBRIG and P. L. SALVATORI. Third edition, 1957. Pp. 780, 197 figs, bibl. Obrig Lab. Inc., New York. ($15; £6. 15*s*.)

This book sets out "to teach the fitting of contact lenses to ophthalmologists, optometrists, and opticians". Chapters on the optics of contact lenses, plastics, technique of making moulds of the living human eye, the fitting of moulded plastic contact lenses. the "Lacrilens contact lens", and XII, XIII, and XIV on Corneal contact lenses, some 250 pages in all, contain sound practical information.

In the first 170 pages "Anatomy" is well done; "Biochemical and Physiological Data" contains several pages of Tables which make little contribution to the purpose of the book; a long section on "Ophthalmology of Contact Lenses" is a compilation of ophthalmology, pathology, sociology, and psychology. The early part of the book is copied slavishly from the 1942 edition; it is unbalanced, often misleading, and much of it inevitably out of date. As examples, we may cite "Diseases of the Retina, Retinitis Pigmentosa" to which no less than two and a half pages of text is devoted in order to mention two individual patients with this condition who have been successfully fitted with contact lenses. Both were high myopes and one had corneal scarring in addition. Some sound information under the heading "Vocational Uses" is marred by special pleading, some of it dangerous. Thus, under "Aviators" "The safety of contact lenses in aviation is without question". In fact the hazard that contact lenses will become intolerable or that vision may become obscured during flight, is very real. The matter is, however, clinched by the statement: "a German military aviator was reported as shot out of his plane. When he landed, practically every bone in his body was broken, but his contact lenses were intact". They may very well have cost him his life. Careless substitution of "We" for "The Author" now that Salvatori has joined Obrig in the authorship seems to contradict claims to originality previously made by Obrig in several instances, notably on page 185. This should be put right.

As indicated, the heart of the book lies between pages 175 and 400 approximately. Almost all of this is sound and well worth reading, presenting the detailed work of fitting and moulding, the optics of the problem, and the approach to the patient, competently and, for the most part, unexceptionably. It is, however, almost all rule of thumb and no underlying principles have been evolved.

Beyond this we have no less than 305 pages devoted to a detailed reprint in English of perhaps all the contact lens Patents that have been registered. The authors suggest that the printing of this vast amount of material will enable the reader to trace the development of contact lenses from the beginning to the present time. As 45 pages have already been devoted to the history of contact lenses this seems unreasonable.

The bibliography of 28 pages of small print is exhaustive. A selected bibliography of formative contributions would be of more value to the prospective contact lens fitter. The Index is adequate: like the reviewer, it gives up at page 429.

Perhaps the clue to the strangeness of this book to an English reviewer is to be found in the fact that it is compiled by a manufacturing organization chiefly concerned to present its products to prospective users in America. In the U.S.A. the eye may not be rendered anaesthetic except by a physician or in his presence. Throughout the book it is assumed that a physician will have advised upon the wisdom of supplying a contact lens, and will be present when a mould is taken or an anaesthetic is used. A great deal of the information which seems unbalanced may therefore be designed to put the American fitter into the medical picture and not to teach him ophthalmology. The authors, throughout the

book, are careful to indicate the complications of contact lens fitting, particularly with regard to corneal lenses. As a rule their claims are fair and the patients' interests are protected.

Contact Lens Routine and Practice. By NORMAN BIER. Second edition, 1957. Pp. 264, 177 figs. Butterworth, London. (50*s*.)

This second edition is handsomely printed. The illustrations, both photographs and line drawings, are excellent and clearly related to the text.

The routine and practice whereby the wide range of contact lenses (both the full-sized type and the various corneal types now available) may be fitted are described in detail. This is all sound practical material, well organized in its presentation, clear in its intention, and competent in its practical methods. If it is wished to fit all the lenses described, then this book is an excellent guide to doing so but it is a pity that the book is so lacking in clearly stated preference. By now the author must have reduced his choice to only a few and this for sound practical reasons. This lack of direction may be related to the author's wish not to name manufacturers or to appear to favour one product above another, but it may be argued that such informed guidance is a primary necessity in a book of this kind. This catholicism leads the author to list some two hundred trial lenses to cover the various approaches described—this could probably be reduced to a quarter were a recommended procedure defined, eliminating the dead wood.

In only one matter does the reviewer seriously disagree with this book. This is with regard to the routine use of a "tolerance trial". The author fits approximate lenses out of stock—necessarily without adequate optical correction—and sends the patient out with them for 3 hours. The results to be obtained with competently fitted contact lenses as opposed to any stock approximation are so incomparably better in most cases that this experience, so far as the patient is concerned, can only be misleading. The necessity for such a patient to remain within immediate call of the fitter should discomfort or veiling develop is not mentioned—indeed it is stated that these patients have usually developed veiling by the time they return. This procedure seems to be a strange survival from the bad old days of "ready-made" fittings. It might be defended as a means of selecting those patients of whom it may be said "if they will put up with that they will put up with anything", but this can hardly be the intention.

Conceding its excellence as a guide to the fitting of almost all the contact lenses on the market at the present time, the reader must often be dismayed at the vast amount of technical minutiae described. Indeed there must be very few people who could read this book through with real practical comprehension. At this point we join issue with both the author and with the foreword written by F. A. Williamson-Noble in which it is claimed: "It [the book] will become a classic and the principles he lays down will remain valid for as long as contact lenses continue to be fitted. As he [the author] himself says, although minor improvements will no doubt be discovered, the fundamental principles of technique have now been established". The reviewer would suggest that this is exactly what this book does not accomplish. It does not define any unifying theory, and without such a theory no final principles can be enunciated. The book is a manual of contact lens routine and practice and as such it is very good indeed.

Applied Physiology of the Eye. By H. WILLOUGHBY LYLE and T. KEITH LYLE. 1958. Pp. viii + 342, 32 figs. Baillière, Tindall and Cox, London. (45*s*.)

From every page of this book there emerges the personality of H. Willoughby Lyle and most of them conjure up a picture of him revelling in acting as an examiner. The subject was Lyle's specialty—the physiology of the eye in its widest clinical applications; and these applications are indeed wide, covering as they do most of ophthalmology and much

of general medicine. Here we have everything—or almost everything—we have to know of the anatomy and physiology of the eye and many of its abnormalities and diseases, with a pronounced emphasis on ophthalmo-neurology. That all this learning should be compressed within so small a compass seems extraordinary; and, as needs must be, much of the information is simplified and much of the teaching so dogmatic as to verge upon the dangerous. We should all sigh with relief if the whole story of the congestive type of primary glaucoma were encompassed within an "ocular hypertension of thalamic and hypothalamic origin, the result of increased functioning of the parasympathetic centre in the more central portion of the hypothalamus near the tuber cinereum and of the parasympathetic nerves". It may be so; but who knows? As a help, however, to the student to pass his post-graduate examination in ophthalmology, the book cannot be surpassed in present-day literature; the examinee who satisfied Willoughby Lyle was either good or unusually fortunate; but it is to be hoped that having passed he will not imagine that he knows all that is in ophthalmology.

The manuscript was written before the senior author's death in 1956, essentially by himself, but with the help of his son; and since that date the latter has corrected it, brought it up to date, and seen it through the press.

Axenfeld's Text-book and Atlas of Ophthalmology. 10th edition, 1958, edited by HERMANN SERR. Pp. 786, 685 text figures, 12 col. pl. Fischer, Jena. (64.50 D.M.).

Axenfeld's standard text-book has long been known as one of the best advanced handbooks in ophthalmology. The tenth edition has now appeared under the general editorship of Hermann Serr (Heidelberg), the various chapters being contributed by this author and a team of fourteen of the best-known ophthalmologists in Germany. Comprehensive in its scope, lavish in its detail, and beautifully produced and illustrated, the volume is representative of the best in German ophthalmology and provides an excellent handbook for the senior student.

MESSAGE OF THANKS

I am claiming the privilege of the hospitality of this Journal for a personal message to many of my friends and colleagues.

On my 60th birthday I received a Birthday Book which is so extraordinary that it is quite out of this world, containing messages from ophthalmological and medical bodies, from practically every country in the world, as well as delightful messages from many individuals. To thank the latter individually is a pleasure; to thank the official bodies is easy and an equal pleasure; but to thank all those from the various Societies who have done me the great personal honour of signing the pages of the book is an impossible task, for they are numbered in thousands. Words are a very imperfect medium for expressing the thoughts which I feel, and I hope that those who showed me so much kindness will accept my thanks through this letter.

STEWART DUKE-ELDER.